Statistical Evaluation of Projected Traffic Growth

Transportation Research, Education, and Technology Transfer ITQ
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Task 5

Final Report

Traffic Growth Forecasting System

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Submitted by

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1.Executive Summary

Traffic growth forecasting plays a pivotal role in achieving a variety of PENNDOT goals and objectives, including transportation planning by PENNDOT and its planning partners, air quality planning and conformity analyses, calculation of performance measures, and operation and management of the roadway transportation system for both passengers and freight.

In this study, the Michael Baker Jr., Inc. Team (Baker Team) developed a traffic growth forecasting system that incorporates traffic data from PENNDOT's Traffic Information System and socioeconomic data. In particular, the Baker Team:

- Finalized and prioritized goals and objectives for improved traffic growth forecasting in Pennsylvania and established a set of criteria for evaluating candidate forecasting methods against PENNDOT goals and objectives.
- Synthesized the state of art research on forecasting traffic growth from a variety of literature and surveyed the state of practice among states and transportation planning organizations.
- Identified available data sources, including traffic information and socioeconomic data and forecasts, and in particular, identified the linkages between traffic growth forecasts and PENNDOT's Traffic Information System, and recommended a consistent set of socioeconomic forecasts.
- Evaluated the candidate methods versus the PENNDOT-approved decision criteria and developed consensus on a short list of traffic forecasting approaches for detailed study.
- Conducted a detailed study to test several models. Specifically, we analyzed historical traffic growth patterns and historical socioeconomic growth patterns at different levels of geography, developed regression models based on historical traffic and socioeconomic growth, and evaluated the predictive power, validity, and reliability of statistical models.
- Identified a preferred traffic growth forecasting method for implementation.

While the same traffic forecast can be used to serve multiple objectives and goals, each objective or goal requires different degrees of accuracy, details and specific time horizons. In this study, the Baker Team identified the goals that traffic growth forecasting can serve in the Commonwealth of Pennsylvania. In conclusion, this proposed traffic growth forecasting system should primarily serve the priorities of PENNDOT goals and objectives in the following order:

- Transportation planning
- Air quality planning
- Funding allocation
- Other purposes

To serve these goals and objectives, VMT forecasts for four functional classifications—urban interstate, urban non-interstate, rural interstate, and rural non-interstate—were identified as the focus of this forecasting system. With these priorities identified, the proposed forecasting system should:

- Incorporate a statewide county-level approach that produces consistent VMT growth forecasts across the state.
- Utilize historical traffic growth data and socioeconomic and land use variables.
- Minimize any bias among or between highly urbanized, suburban, small urban and rural counties/regions through including area type classification (urban vs. rural) and socioeconomic and land use variables.

Different regression models were developed, and a set of models was used to forecast VMT for planning horizon years 2010, 2020, and 2030. Forecasting results were evaluated, based on

- Forecasting Trend vs. Historical Trend,
- Growth Magnitude at the County Level,
- Growth Magnitude at the State Level,
- Geographic Patterns.

In summary, major conclusions and recommendations are as follows:

- Regression models best meet PENNDOT needs for a statewide VMT growth forecasting system. In particular, regression-based forecasting models provide a consistent statewide forecasting framework.

- Data needed for implementing a regression-based forecasting system are readily available, updated annually, and reasonably priced. The PENNDOT database maintained by Bureau of Research and Planning provides an excellent source for VMT, lane miles, and other key variables. State profile database for Pennsylvania, produced by Woods & Poole Economics, is recommended as the data source for socioeconomics.

- It is recommended that PENNDOT forecast VMT growth as a range and averaged middle point, as follows:

    1. The upper boundary of the VMT forecasts (all facility classes) is based on the household-based county-level regression models (MODEL HH). This model produces the most consistent and logical forecasts among candidate models.
    2. The lower boundary of the VMT forecasts (interstate classes) is based on the household-based county-group-level regression models.
    3. The "middle point estimate" of forecast VMT is created by averaging the upper and lower boundaries of forecasts from the two models at the state level, and then adjusting the forecasts from MODEL HH at the county level so as to match the averaged forecasts at the state level.

- The regression models should be updated annually, based on new VMT and socioeconomic data.

- Potential future investigation includes evaluation of air quality implications of the recommended VMT forecasting system and incorporation of intra-county level socioeconomic and land use variables in the forecasting system.

2. Defining and Prioritizing Goals and Objectives

Traffic growth forecasting has been used to achieve a variety of goals and objectives in the Commonwealth of Pennsylvania. While the same traffic forecast can be used to serve multiple objectives and goals, each objective or goal requires different degrees of accuracy, details and specific time horizons. This subtask will help establish the requirements for traffic growth forecasting, specifying the criteria or thresholds for evaluating traffic growth forecast methods and building consensus on the required accuracy of the final product.

The Baker team has identified the following goals that traffic growth forecasting can serve in the Commonwealth of Pennsylvania:

- Transportation planning
- Air quality planning and federal compliance
- Funding allocation
- Operation and maintenance

Through meeting with the PENNDOT project team and interviewing key potential users (see the appendices for detail), the Baker team gains a better understanding of the importance of traffic forecasting to different PENNDOT functions and the priorities that this particular traffic growth forecasting system should serve.

First, traffic growth forecasting is critical to the transportation planning process. Whether highway or transit, transportation infrastructure investments are identified and prioritized using travel demand forecasts. Efficient and equitable transportation planning – <u>a reliable and consistent analytic input to applying scarce PENNDOT resources to maintain and improve the roadway system</u> - relies on accurate traffic growth forecasts. Whether it is a Metropolitan Planning Organization (MPO), a Rural Planning Organization (RPO) or PENNDOT, traffic growth forecasting plays a fundamental role in the transportation planning process—transportation improvement programs (TIPs), 12 year plan, and long-range plans (LRPs).

MPOs in Pennsylvania (see Figure 2-1) update their short-term TIPs and LRPs based on the federal regulations. Seven of these MPOs maintain travel demand models and use these models to produce traffic growth forecasts. As will be discussed in the following section on traffic forecasting methods, these models use detailed socioeconomic and travel survey data and detailed transportation analysis zone (TAZ) structure. These models are calibrated and validated so that simulated traffic volumes from the models match ground traffic count volumes to a reasonable degree at the regional level. While these models are developed primarily for evaluating TIP, LRP, and air quality conformity, they are also used for corridor studies and other purposes.

The seven MPO model sets encompass only 20 of Pennsylvania's 67 counties. These models and their underlying data sets vary significantly regarding the quality and age of underlying databases, and contain limited information regarding external forces. As such, they may not be prime candidates for incorporation into a statewide approach, but do offer a potential for cross-checks of the algorithms and data being tested in this project. For detailed discussion, see the section on review of traffic information system and travel demand models.

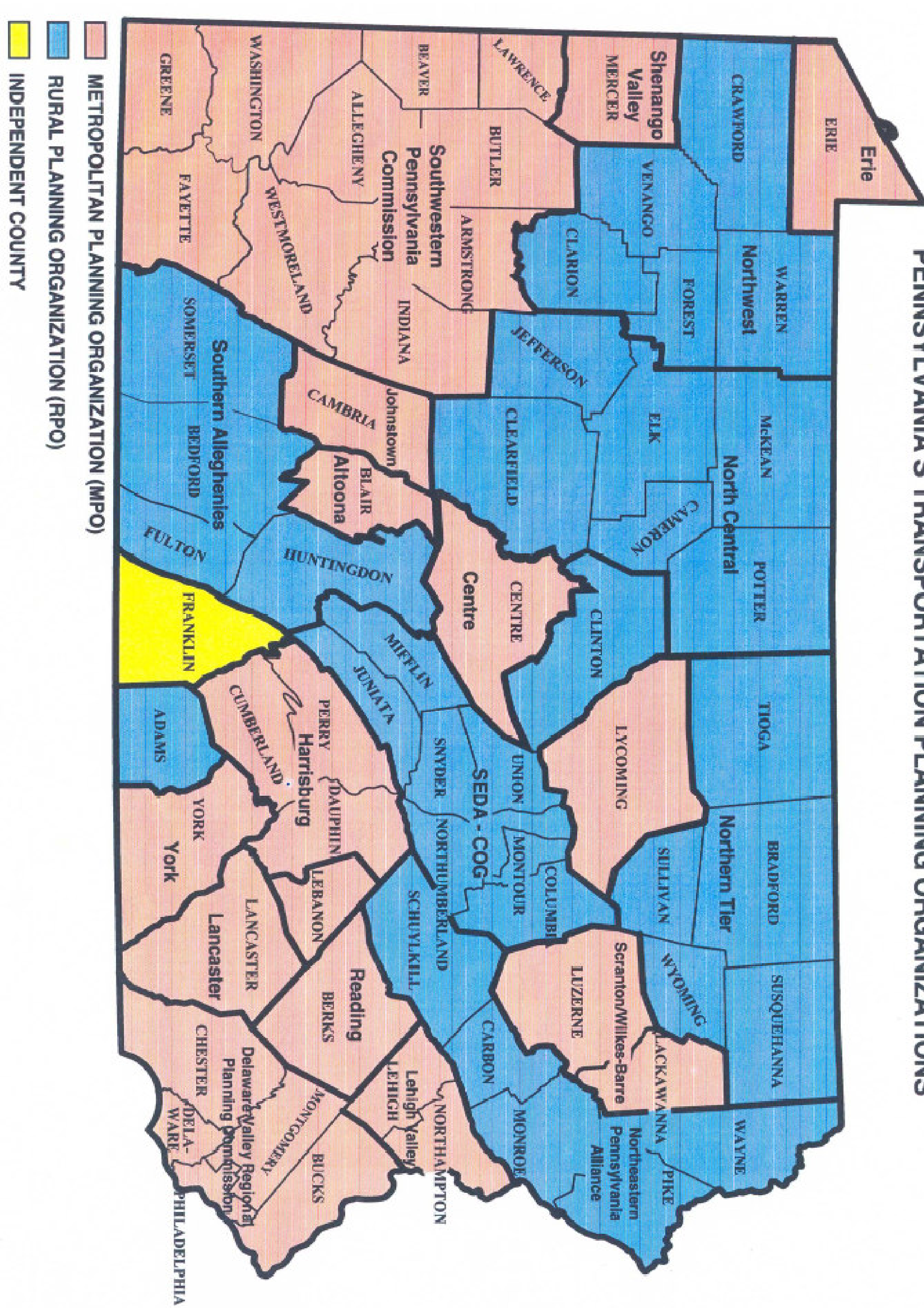


Figure 2-1. MPOs and RPOs in the Commonwealth of Pennsylvania

RPOs in Pennsylvania (see Figure 2-1) do not have travel demand models for their short-range and long-range transportation planning. They rely on the data and tools that PENNDOT can provide. Clearly, this is an important missing piece in the statewide planning. As of this writing, PENNDOT is in the initial stage of developing a statewide travel demand model and does not have a quantitative forecasting tool that can be used to serve counties that are not encompassed in a travel demand model.

As can be seen, the traffic growth forecasting system that is to be developed in this project should serve an important link in the transportation planning process in Pennsylvania. It will provide a much-desired tool for planners at PENNDOT and RPOs to do short-range and long-range planning in rural planning areas, while complementing (not replacing) the existing travel demand models in metropolitan planning areas.

Second, traffic growth forecasts are pivotal in air quality planning and federal compliance. The Clean Air Act Amendments (CAAA) of 1990, the Transportation Equity Act for the 21st Century (TEA-21) of 1998, and the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) all mandate the integration of air quality into the transportation planning process. Proposed TEA-21 reauthorization language indicates that basic language and requirements will not change significantly. This legislation includes measurement and projection of VMT for planning, air quality, congestion management and other purposes.

The United States Environmental Protection Agency (USEPA) requires state DOTs and MPOs to accurately estimate, forecast and track VMT. PENNDOT undertakes the VMT forecasting for all areas without MPO models and assists elsewhere. VMT forecasts are important components of air pollutant emission and air quality forecasting, and are critical in the determination of air quality conformity.

The application and use of forecasted growth factors can have a significant impact on regional air quality analyses conducted for nonattainment and maintenance areas for which USEPA requirements exist for conformity, state implementation plan (SIP) or planning activities. Conformity requires a demonstration for most TIPs and LRPs that emissions in future years are lower than or equal to either base year (2002 emissions) or a SIP emissions budget (where applicable). Inability to make an affirmative conformity determination results in a TIP or LRP being unacceptable and certain projects non-fundable by USDOT. Planning activities may include analysis of potential measures to reduce emissions, such as reducing trips, VMT, and/or cold starts or measures that raise or lower speeds to a more emissions-efficient level. As of August 2004, 37 Pennsylvania counties are nonattainment for ozone, and 13 - 22 counties likely to be designated nonattainment for PM2.5 in late 2004.

Additionally, EPA requires that emissions inventories be conducted on a triennial basis. PENNDOT is the lead agency in developing the underlying data and producing emissions outputs for on-highway vehicles (“mobile sources” for past, present and future years, and providing this information to the Pennsylvania Department of the Environment. This data is developed by county, and aggregated to metropolitan and nonattainment area.

Accurate mobile source emissions analysis relies, in large part, on accurate estimates of vehicle miles of travel. The relationship is direct and indirect: Directly, it impacts the application of emissions factors (grams/mile) to VMT. Indirectly, VMT is used to estimate speeds by facility class by time period: underestimation of VMT may result in speed estimates higher than appropriate, while overestimation of VMT may result in speed estimates lower or higher than appropriate. Both situations may influence emissions factors for criteria pollutants and their precursors. Unrealistically high traffic growth rates may overestimate future year emissions and require costly emission control strategies. In addition, conformity analyses conducted in these regions must remain at or below the emission target levels set by the SIP to prevent lapses in the TIP and LRP projects. If the growth rates used to develop SIP emission estimates significantly underestimate travel growth as compared to actual growth as reported in RMS and HPMS, potential conformity problems could arise.

Pennsylvania updates its traffic-related inputs triennially to satisfy EPA regulations. Future year forecasts are updated in three ways: (1) in accordance with the TIP/LRP cycle, which parallels the 12 Year Plan schedule, (2) as a new or revised TIP or LRP may otherwise require, and (3) as EPA may require. The triennial update of the most recent year's VMT data (e.g., rectified to HPMS, etc.) forms the basis for future year projections. The biennial TIP/LRP/12 Yr Plan cycle has historically triggered the need for updated future year projections (up through the end of the LRP) for each nonattainment area, which involves at least 37 counties. For counties with travel demand models, forecasts based on PENNDOT data are compared with those from travel demand models to ensure reasonableness and consistency. For areas without travel demand models, and PENNDOT VMT data is the sole source of VMT, speed, and link data.

As a result, in future conformity rounds, actual VMT growth that was previously forecasted in the SIP will then be obtained from the RMS and HPMS reported totals directly. The above discussion illustrates the importance in developing accurate growth rates and the potential implications of overestimating or underestimating such growth factors.

Like transportation planning tools in different parts of the State, MPOs rely on travel demand models to provide traffic growth forecasts for air quality planning. PENNDOT does not currently have a quantitative tool that can be used to produce consistent traffic growth forecasts statewide, particularly for rural and small urban planning areas. The forecasting system to be developed in this project should serve fill the gap. In particular, it should generate statewide VMT forecasts for major functional classifications. PENNDOT staff has indicated that four functional classifications—urban interstate, urban non-interstate, rural interstate, and rural non-interstate—are very important. The proposed forecasting system should focus on this very important dimension.

Third, VMT estimation and traffic growth forecasts impact funding for both current and short-range transportation improvement programs. TEA-21 allocates thirty-five percent of the apportionment funds based on the ratio of total VMT on the principal arterial system in a state to the total nationwide VMT on the same classes of roads. As such, traffic growth forecasting is vital in ensuring that Pennsylvania continues to receive an equitable share of the available funding.

Table 2-1 shows how HPMS data are used in the Federal-Aid Highway Program apportionment formula (FHWA 2000). As can be seen from the table, VMT is an important metric used for federal fund allocation. In particular, VMT on the interstate highway system and VMT on the principal arterial system receive heavy weights in the federal fund allocation formula. This is another indication for the importance of VMT as a metric and interstate as a classification, on which the proposed forecasting system should focus its attention. Better VMT forecasts will allow PENNDOT to improve its funding forecasts and budgets accordingly.

Table 2-1. HPMS Data Used for Apportionment

Fund	Factors	Weight
Interstate Maintenance	Interstate System Lane Miles	33 1/3 %
	Vehicle Miles Traveled on the Interstate System	33 1/3 %
National Highway System (NHS)	Lane Miles of Principal Arterial Highways (excluding Interstate System)	25 %
	Vehicle Miles Traveled on Principal Arterial Highways (excluding Interstate System)	35 %
	Total Lane Miles of Principal Arterial Highways divided by the State's Population	10 %
Surface Transportation Program (STP)	Lane Miles of Federal-Aid Highways	25 %
	Vehicle Miles Traveled on Federal-Aid Highways	40 %
Highway Safety Programs	State Population	75 %
	Public Road Miles	25 %

Source: FHWA (2000)

Fourth, traffic growth estimation helps PENNDOT in its day-to-day operation and management of the Commonwealth's transportation system. It provides useful information to a variety of PENNDOT functions such as traffic engineering, accident analysis, winter service operations planning, highway maintenance and construction. These PENNDOT functions require very detailed information about highway conditions, both spatially and temporally. This is not the scale that this project will be used to develop the forecasting system, but traffic growth forecast will be helpful to these PENNDOT functions.

In summary, this proposed traffic growth forecasting system should primarily serve the priorities of PENNDOT goals and objectives in the following order:

- Transportation planning
- Air quality planning
- Funding allocation
- Other purposes

To serve these goals and objectives, VMT forecasts for four functional classifications—urban interstate, urban non-interstate, rural interstate, and rural non-interstate—should be the focus of this forecasting system. Traffic volume growth forecasts, although important, have been covered in other studies at the project, corridor, or metropolitan levels and are not a priority in this study.

With these priorities being identified, the proposed forecasting system will

- Be a statewide county-level approach that produces consistent traffic growth forecasts across the state.
- Incorporate historical traffic growth data and socioeconomic and land use variables.
- Minimize any bias among or between highly urbanized, suburban, small urban and rural counties/regions through incorporating area type classification (urban vs. rural) and socioeconomic and land use variables.

Testing of multiple methods will be done, and a preferred forecasting method will be selected for this forecasting system. To compare different candidate forecasting methods, evaluation criteria need to be established. Saha and Fricker (1987) used eight goals of analysis for their traffic growth forecasting study and established four criteria for variables selections. Based on their study and the PENNDOT needs, the criteria for evaluating the statistical models may include:

1. The models should explain more than fifty percent of the variation (R^2>50)
2. The relative predictive errors will be among the lowest.
3. Mean Absolute Percent Error or Root Mean squared error (RMSE) will be minimum.
4. The number of predictor variables should be adequate and compatible with the number of observations.
5. Estimated coefficients should be statistically significant at an alpha level of 0.05 or 0.1.
6. There should be no discernible patterns in the residuals.
7. Data availability and reliability are good for independent variables.
8. Frequency of update meets PENNDOT needs.
9. Cost is reasonable to update and maintain the forecasting system.
10. The models can differentiate cars and light trucks from heavier vehicles, if possible.
11. The models can make forecasts by county or logical group of counties.
12. The models can provide forecasts for horizons consistent with short- and long- range plan milestones.

This set of twelve criteria will be used to evaluate candidate forecasting models in this project.

3. Reviewing State of the Art and Practice in Traffic Growth Forecasting

Traffic growth can be measured in different ways. For some people, traffic growth means increase in traffic volumes, which can be measured in annual average daily traffic (AADT). For others, vehicle miles of travel or vehicle miles traveled (VMT) is the common metric used to monitor the changes in travel in the past and project the potential changes in the future travel. As discussed below, VMT incorporates both traffic volume and travel distance, and is therefore a more comprehensive measure in the estimation.

While the growth in traffic volumes is the basis of most forecasting efforts, VMT growth is pivotal in understanding the impacts of increased traffic volume. VMT estimation and growth forecasts have received much attention in federal legislation such as CAAA, ISTEA, and TEA-21.

Based on the data used, traffic growth estimation and forecasting methods can be classified into three categories: traffic-count-based methods, socioeconomic-data-based methods, and travel demand forecasting models. Based on forecasting techniques, traffic growth forecasting can be grouped into categories: trend/growth factors, time series, regressions, and alternative statistical methods.

3.1. Traffic Growth Forecasting Methods—Based on the Type of Data Used

3.1.1. Traffic Count Based Forecasting

Traffic-count based methodologies are the most common approaches used to forecast traffic growth. In particular, the USEPA recommends use of HPMS-based procedures to estimate VMT. The HPMS-based VMT estimation procedure includes AADT and highway length estimation by functional class. Specifically, the procedure includes calculations of the following by functional class:

- Total traffic volume,
- Sample size,
- Average traffic volume,
- Highway miles, and
- VMT.

AADT estimation by functional class is generally based on the three types of count procedures:

(1) Continuous counts,
(2) Coverage counts, and
(3) Special needs study count.

The continuous counts program is established to collect traffic volume and speed data on a continuous basis, using automatic traffic recorders (ATRs) 24 hours a day and 365 days a year. The continuous count stations are limited in number and are strategically located throughout a state. The collected data are primarily used to develop seasonal, daily, and other adjustment factors, which are used to expand short-term sample counts.

Short duration count programs include coverage counts and special needs counts. The HPMS coverage count program includes short-duration sample counts that are collected through random sampling to ensure the adequate geographic representation and statistical validity of traffic count data in the public roads throughout a state. The FHWA recommends that each coverage roadway segment be counted at least once every six years, and at a minimum each of the HPMS universe/sample sections are counted once every three years. When counts are not undertaken for a year, growth factors are usually used to estimate traffic volume for this year. These growth factors are estimated based on historical traffic growth data and may be used for forecasting traffic growth in the future.

Count-based methods can be biased because of sampling size, frequency, or representation, and the extrapolation from the sampled sites to system wide (regional or statewide) total. Factors are used to correct for temporal variations, equipment types, and counting cycle. Extrapolation of the sample data to the entire network is usually based on expansion factors accounting for variations among functional classes and area types. However, these expansion factors ignore factors that could affect traffic growth in the future such as link attributes, land use and socioeconomic characteristics of the area.

Strengths

- Traffic count data are readily available and routinely updated statewide.
- They are generally simple and easy to implement.
- They cover the whole state and provide a consistent forecasting framework.
- They have the potential of providing forecasting at detailed level such as functional types and vehicle types.
- HPMS data are consistently reported for most data items and allow comparison among states.

Weaknesses

- There are uncertainties associated with sampling and extrapolation.
- They generally do not account for trip-making processes and factors that drive traffic growth such as socioeconomic variables.
- They rely heavily on the assumption that traffic growth will behave in the same or similar manner as the past, regardless of demographic, land use and other factors

3.1.2. Socioeconomic Data Based Methods

Socioeconomic-data-based methods do not rely on the characteristics of the roadways but instead focus on factors that affect an individual's travel behavior in a region and use these as the basis of estimating traffic growth. Using social economic data to predict travel changes attempts to estimate traffic growth at a more fundamental level, while at the same time using variables that can project into the future with a higher degree of confidence. Typically, socioeconomic-based methods use data such as:

Households	Employment
Household size	Number of licensed drivers
Household income	Odometer readings
Vehicle per household	Fuel taxes
Population	Fuel sales

Data sources include: Census, the National Personal Transportation Survey (NPTS), American Travel Survey (ATS), and Residential Transportation Energy Consumption Survey (RTECS). NPTS is a national survey of daily personal travel. It was conducted in 1969, 1977, 1983, 1990, and 1995. The American Travel Survey (ATS) obtained information about long-distance travel of persons living in the United States. ATS was conducted in 1995. The NPTS was combined with the American Travel Survey (ATS) to form the National Household Travel Survey in 2001. NPTS data include:

- Household level data – size, income, education, etc.
- Motor vehicle information – estimates of annual VMT, age, etc.
- Public transportation - use, availability, etc.
- Drivers – annual miles driven etc.
- Trips – length, travel time, etc.
- Description of geographic area characteristics for households and workplaces.

Truck travel data include the Commodity Flow Survey (CFS), the Vehicle Inventory and Use Survey, and the International Fuel Tax Agreement (IFTA) truck mileage database. The amount of commercial activity reported in the 1993 CFS, reported in ton-miles, was for travel within, to, from and through each of the 50 states and the District of Columbia. Changes in the survey format for 1997 prevented the calculation of these travel estimates.

All commercial enterprises that undertake motor carrier operations in the United States and Canada are expected to apply for fuel tax licenses. The International Fuel Tax Agreement (IFTA) is an agreement among 58 jurisdictions in the United States and Canada to facilitate interstate commercial vehicle travel among the jurisdictions. The IFTA requires the carriers to report the total annual miles traveled by all qualified vehicles for tax estimation purposes.

Vehicles qualify for licensing under the IFTA program if they meet any of the following requirements and configurations:

- Two axles and a gross vehicle weight (GVW) exceeding 26,000 pounds,
- Two axles and a registered weight exceeding 26,000 pounds,
- Three or more axles, regardless of vehicle weight,
- Passenger vehicles that have seats for more than nine persons, and
- Combined vehicle weight exceeding 26,000 pounds (for combination vehicles).

However, the following vehicles are exempt from the IFTA program:

- Recreational vehicles,

Travel surveys have been used to estimate VMT based on household travel characteristics and on licensed driver characteristics. Indiana DOT sponsored a study to develop unbiased statewide VMT estimates for personal and commercial travel (Friker and Kumapley 2002). The study tested three methods—licensed driver-based, household-based, and fuel-tax-based. These methods are all based on socioeconomic data (see the Case Studies section for the detail)

To forecast state tax revenues, the ODOT Financial and Economic Analysis Section adopted a fuel-based approach to estimating and forecasting VMT. Total VMT is divided into three categories— Light vehicle VMT, Medium-Heavy Vehicle VMT, and Heavy Vehicle VMT. For the first two categories, ODOT uses monthly fuel consumption data, fuel refund claims, and national miles-per-gallon estimates to calculate VMT. For heavy vehicles, VMT is estimated using actual reported mileage from weight-mile tax records and adjustment factors (see the Case Studies section for the detail)

These methods also have limitations, as the data sources employed were not designed specifically for estimating VMT. Potentially significant biases can result from some data sources and extrapolation from sample to system wide VMT can lead to additional inconsistencies. Furthermore, these methods do not generate VMT estimates by functional class because of the limitation in the source data.

Strengths

- Account for major forces that drive traffic growth, including socioeconomic factors.
- Socioeconomic data are readily available and routinely updated.
- Encompass the whole state and provide a consistent forecasting framework.

Weaknesses

- Do not simulate trip-making processes.
- Provide little detail in forecasting such as detailed functional and vehicle types.
- Potentially significant biases can result from some data sources and extrapolation.
- Travel survey data may be biased because of low response rates, low response quality in trip length, and under-reporting particularly for short trips.

3.1.3. Travel Demand Forecasting Models

Travel demand forecasting models can also be used to estimate and forecast growth in traffic volumes and VMT. These models are generally developed and validated using household travel surveys, socioeconomic data, land use data and traffic counts. That is, travel demand modeling takes into account additional important variables and data sources used in the two methods discussed above. These models are designed to simulate travel behavior of trip makers, including:

- How many trips are produced and attracted at each location,
- How may trips are made from each origin to each destination,
- How trip-makers get from an origin to a destination
- Which path a trip-maker takes to get from an origin to a destination

These trip-making processes are simulated as trip generation, trip distribution, mode choice, and traffic assignment in the traditional travel demand models. The road system is simulated as a simplified network in the model. The models yield traffic volumes in individual links based on socioeconomic and highway inputs. VMT by functional types or time periods of day can be estimated, simply multiplying link volume by link length.

To the extent that travel demand models can simulate travel characteristics and behavior changes over time in these trip-making processes, these models can be used to forecast system wide (regional) travel. For example, socioeconomic data such as population, number and size of households, and number and types of employment are critical input variables in these models. If population and households are forecasted to grow (decline) in the next twenty years, these models will forecast some degree of increase (increase) in system wide travel.

Travel demand models have been developed primarily to evaluate future transportation system performance, not system-wide (regional or statewide) travel. Despite the recent progress in travel demand modeling, it is still difficult to replicate traffic patterns on the ground and errors can be introduced in various stages of these usually complex modeling processes. Differences between traffic counts and simulation volumes are common even after validation of the process. Local traffic is generally not accounted for in a travel demand model, and travel demand models are not available for every county in Pennsylvania, nor does a statewide model yet exist or is planned that would provide the level of detail desired by BPR.

Strengths

- Travel demand models usually simulate trip-making processes and account for major forces that drive traffic growth, including socioeconomic factors.
- Readily available and routinely updated at major metropolitan areas.
- If developed for policy and planning applications, travel demand models can be used to evaluate policy implications and the sensitivity of VMT to policy input.
- VMT by functional classes, area types, and jurisdictions can be estimated and forecasted.

Weaknesses

- Do not generally account for the local travel because most local and minor roads are not included in the model network.
- Generally do not cover the whole state and cannot be used for statewide traffic forecasting.
- Provide less detail than can be obtained from traffic count-based methods, such as detailed time of day, daily, seasonal, and detailed vehicle types.
- Extensive data and resources are required to calibrate and validate a model.

3.2. Traffic Growth Forecasting Methods—Based on Forecasting Techniques

3.2.1. Growth Factors

The growth factor method is the most popular technique used to do traffic growth forecasting. It is simple and easy to develop and implement. Historical traffic count data and estimation of annual traffic growth rates are used to project future volume of VMT

These traffic growth rates are either applied directly to future years or adjusted based on some assumptions. Direct application of growth rates are based on the assumption that past traffic growth trends will continue in the future. This assumption may hold true for a short-term forecasting. For a long time horizon, this assumption may be problematic. Traffic growth may exhibit varying temporal patterns for different areas, which are in different development stages over the years. A rapidly growing, urbanizing area shows steep annual traffic growth now, but this degree of traffic growth may or may not continue indefinitely.

For many rural areas that are far from major urban centers, economic activities are steady and so is traffic growth. In well-developed metropolitan areas, economic growth may have already run its course and so may traffic growth. Growth factors for these areas may be small and stable in the future.

Polzin, Chu, and Toole-Holt (2004) analyze the trends of socioeconomic conditions that drive VMT growth and conclude that these socioeconomic factors have reached a moderating stage. They argue that future VMT growth would be moderate.

Strengths

- Traffic count data that are used for deriving growth factors are readily available and routinely updated statewide.
- Generally simple and easy to implement.
- Cover the whole state and provide a consistent forecasting framework.
- Traffic growth factors can be developed to provide forecasting at detailed level such as functional types and vehicle types.

Weaknesses

- There are uncertainties associated with traffic count sampling and extrapolation.
- Generally do not account for trip-making processes and factors that drive traffic growth.
- It is problematic to assume that for a long time horizon, traffic growth will behave in the same or similar manner as the past.

3.2.2. Time Series Models

In time series models, past trend is the key to predict the future. Of course, the assumption is that the traffic growth will behave like in the past. Past trends are modeled as linear or curvilinear equations; Traffic is dependent variable and year is independent variable.

Benjamin (1986) presents a procedure for forecasting average daily traffic using time series model. The procedure assumes a logistic function for modeling daily traffic volume over a period of years. The results from the time series model were compared to those from a travel demand model. The time series technique produces results that are close or closer to the observed traffic volume data for small, steady growth areas.

Growth factors are a special case of time series methods. Growth factor method's strengths and weaknesses are also true for time series models. Time series analysis can produce a range of answers, while econometric models provide point estimates. Time series results are sensitive to the data quality. The historical data used to develop time series models are particularly critical to determine if the model is applicable to forecasting the future. If the historical data include only the rapidly growing stage of an urbanizing area, the estimated model may overestimate future traffic growth for a long time horizon. These limitations come from the fact that time series models do not simulate the physical processes that underlying the traffic growth.

3.2.3. Econometric Modeling (Regressions)

Regressions are generally used to describe the relationship between a dependent variable and its explanatory variables. For forecasting traffic growth, explanatory variables may consist of demographic and economic variables as listed above. Model's functional forms may be linear or nonlinear.

Using regression to forecast AADT received early attention in the literature. Neveu (1982) developed a set of elasticity-based regression models to forecast traffic in the rural state highway systems in New York. The dependent variable is AADT. The independent variables include socioeconomic variables such as population, number of households, automobile ownership, and employment. It was found that traffic growth was dependent on different factors for each of three road classes: (1) interstates, (2) principal arterials, (3) minor arterials and major collectors.

Saha and Fricker (1987) conducted a similar study to forecast traffic volume in rural state highways in Indiana. They investigated more independent variables such as vehicle registration, US gasoline price, consumer price index, gross national product, and per capita disposable personal income (nationwide). For each of four rural highway classes (interstate, principal arterials, minor arterials, and major collectors), aggregate models were developed using stepwise regression technique. A series of criteria was used to select independent variables and final models. These criteria include R^2, Cp-Criterion, mean squared error (MSE), number of predictors, statistical significance of estimated coefficients, residual analysis, data availability, data reliability, and data cost. They found that relative changes in state population are significant predictor of rural interstates, relative changes in county population and state population for rural principal arterials, relative changes in county households for rural minor arterials, and relative changes in county population for rural major collectors. In the disaggregate analysis, they developed forecasting models for each count station.

Mohamad et al. (1998) developed multiple regression models to forecast daily traffic on county roads in Indiana. Nine independent variables were included in the model development, including area types of county road location (urban or rural), accessibility to the state highway system, presence of interstate highway in a county, county state highway mileage, arterial mileage, and collector mileage. Logarithmic transformations were conducted on the dependent variable to remedy unequal error variance. Several variable selection methods were used, and R^2 and normality assumption were adopted as the most useful criteria to measure the goodness of a model. They found four independent variables to be significant: county population, county arterial mileage, area types of location, and accessibility. A series of diagnostics was run, and the fitted model was selected for model validation using new traffic data from eight counties that were randomly selected.

Iskander, Jaraiedi, and Thomas (1996) developed linear regression models, incorporating a trend factor and a selected set of socioeconomic variables. The dependent variable is AADT. The socioeconomic variables include population, total income, employment, total vehicle registration, number of licensed drivers, and miles of roadways. These variables were also transformed in square, square root, natural logarithms, and inverse. They were also combined such as population divided by miles, population multiplied by miles, miles divided by population. The selection of variables was done using stepwise regression technique. Regression models were conducted for each road type individually for each county, and then run for each cluster of counties. Final n-variable models were produced with the highest values of R-squared. The authors believed that these models might not be desirable for long range forecasting, particularly when including squares of the variables as a form of transformation. To develop long range forecasting models, they re-ran the models without squares of the variables. Finally, they validated the models against actual AADT data.

VMT estimation and forecasting has been a great interest in recent research, particularly in the debate on the relationship between highway capacity expansion and traffic growth (Noland and Lem 2002). Hansen and Huang (1997) estimated OLS and *Prais-Winsten* econometric models using time series data on VMT for state highways in California, by county and metropolitan area. Independent variables include population, personal income, population density, gasoline prices and lane miles. These are fixed effects models using panel data, and dummy variables were introduced to allow the intercept term to vary over cross-sectional units and time. The panel data and dummy variables allows capturing the influence of variables unknowns or unmeasured in the model. With the panel data, *Prais-Winsten* regressions were used to address the issue of autocorrelations, removing the bias in estimation of parameters.

Two-stage least square regressions with instrumental variables have been used to address the simultaneity and causality issues between road supply (lane miles) and demand (VMT). An instrumental variable is a linear combination of predetermined model variables. Noland Cowart (2000) used a two-stage least squares regression, testing several instruments including urbanized land area. Fulton et al. (2000) used a difference (or growth) model specification and lagged growth in lane miles as an instrument for current growth in lane miles. The dependent variable is the difference or growth in VMT in logarithmic form, and independent variables include lagged growth in lane miles, population, and income per capita. The data used are cross-sectional time series county-level data from the Mid-Atlantic region, including North Carolina, Virginia and Maryland.

Cervero and Hansen (2000) tested a wide range of instrumental variables reflecting political, environmental, and demographic influences. They also used a panel data, consisting of 22 years of observations for 34 California urban counties. Some of variables were found to be correlated with road supply, such as carbon monoxide concentrations, the percent of population that is white, and the political party of the governor. While these variables are useful for examining the relationship between road supply and travel demand, it is not practical to include them in a forecasting procedure.

Strengths

- They account for major forces that drive traffic growth, including socioeconomic factors.
- Socioeconomic data are readily available and routinely updated.
- They can cover the whole state and provide a consistent forecasting framework.

Weaknesses

- They do not simulate trip-making processes.
- They generally do not have provide forecasts as detailed as travel demand models.

3.3. Alternative Statistical Models

Alternative statistical methods have been used to address issues that are difficult to deal with traditional regression modes. Neural Networks Modeling was tested in the Kentucky study of traffic growth rates (Kentucky Transportation Center, 2001).

NNets are computational structures capable of learning from examples and quickly recognizing the patterns they have learned. Learning (or training) and recognition are the two fundamental modes in which NNets operate. For more detailed discussion, see the case study section in the state of practice.

3.4. Traffic Growth Forecasting Methods—Analytical Issues

For the statewide traffic growth forecasting, we need to wrestle with a few analytical issues. In the following, we will discuss two major issues: unit of analysis and VMT estimation.

3.4.1. Units of Analysis

Iskander, Jaraiedi, and Thomas (1996) used cluster analysis to group counties for each road type. To define clusters, four sets of variables were tested:

a. AADT
b. Population
c. AADT, miles of roadway, population, income, employment, number of vehicle registrations, number of licensed drivers.
d. AADT, miles of roadway, and population

The fourth set of variables produced the best results. In addition, three different clustering methods were applied; clustering is done on the basis of Euclidean distances computed from the defining variables:

- Fastclus Procedure—Cluster seeds are first selected and every observation is assigned to the nearest cluster seed. Cluster seeds are then updated and replaced by the cluster means.
- Average Linkage Method— Every observation is initial a cluster itself, and then two closest clusters are merged to form a new cluster, replacing the old ones. This process repeats until only one cluster is left.
- Centroid Method—the same as average linkage method except that the distance is defined as that between two clusters' respective centroids or means.

While this clustering was done for each road type, clustering counties was also attempted for four groups of road types

(1) Urban interstates, other urban freeways and expressways, other urban primary arterials
(2) Minor urban arterials, urban collectors
(3) Rural interstates, other rural primary arterials, minor rural arterials
(4) Major collectors, minor collectors, local.

This clustering effort was unsuccessful.

As shown in Table 3-1, the Traffic Monitoring Guide (2001) recommends the five clusters for grouping highway facilities as a minimum.

Table 3-1. Highway Facility Groups

Clusters	HPMS Functional Code
Interstate Rural	1
Other Rural	2,6,7,8
Interstate Urban	11
Other Urban	12,14,16,17
Recreational	Any

The area/facility groups identified in the Goals and Objective section are basically consistent with the Traffic Monitoring Guide.

3.4.2. Local Road VMT Estimation

States are required to report annually to the Federal Highway Administration (FHWA) aggregate estimates of VMT on the rural minor collector and local functional systems in rural, small urban, and urbanized areas. In 2001, travel on these local area systems totaled over 15 percent of highway VMT in the United States. The current practices used by the States to prepare these local area estimates vary significantly and often are not thoroughly documented. To gain an understanding of the various practices in use, FHWA conducted a survey of the States in April 2002 through its field division offices; the estimation methodologies from 50 States, the District of Columbia, and the Commonwealth of Puerto Rice are summarized Table 3-2.

Table 3-2. State Practices Used to Report VMT

State	Rural Minor Collectors	Locals	State	Rural Minor Collectors	Locals
Alabama	G	G; T (UZA)	Montana	M	M
Alaska	M	M	Nebraska	R	R
Arizona	T	T	Nevada	M	M
Arkansas	M	Z; M (UZA)	New Hampshire	G	M
California	R	R	New Jersey	M	M
Colorado	X	X	New Mexico	G	T
Connecticut	M	A	New York	R	R
Delaware	M	A	North Carolina	R	R
Dist. Of Columbia	--	A	North Dakota	Z	Z; M (UZA)
Florida	M	A	Ohio	A	A
Georgia	M	M	Oklahoma	M	M
Hawaii	R	R	Oregon	R	R
Idaho	M	R	Pennsylvania	M	M
Illinois	M	Z; T (UZA)	Rhode island	A	A
Indiana	M	M	South Carolina	M	A
Iowa	M	M	South Dakota	M	M
Kansas	M	M	Tennessee	A	A
Kentucky	M	A	Texas	M	M
Louisiana	M	M	Utah	A	A
Maine	M	M	Vermont	A	A
Maryland	M	G; T (UZA)	Virginia	M	M
Massachusetts	A	A;M (UZA)	Washington	M	X
Michigan	T	T	West Virginia	M	A
Minnesota	C	R	Wisconsin	R	R
Mississippi	M	M	Wyoming	M	M; T (UZA)
Missouri	M	R	Puerto Rico	T	T

Sources: FHWA (2003). UZA - Urbanized areas

The estimation methodologies are classified in the following major categories:

A – Assign areawide average daily traffic based on some criteria
G – Apply the current traffic growth rate on collectors or higher systems
M – Use a limited sample of short-term traffic counts or a combination of sample counts and estimated average daily traffic
R – Assign the residual of the statewide total VMT minus the higher systems VMT
T - Apply a statewide growth trend based on a factor(s) such as traffic, highway fuel, vehicle registrations, population, etc.
X - Assign a fixed percentage of total area VMT
Z - Assume a zero traffic growth

In this project, local road VMT will not be dealt with separately but rather be part of urban or rural non-interstate VMT. Changes in local road VMT estimation methodology over the years will be examined.

3.5. State of the Practice

Previous surveys have shown that many states use traffic growth rates based on historic data and regression analysis, while others employ socioeconomic and land use data. The University of Kentucky surveyed 45 of the 50 states in 2002. Of the 28 responses received, 22 states used traffic growth rates.

The experience from other states offers useful insights in developing an approach for the Commonwealth. By examining selected DOTs in detail, advantages and disadvantages of the various methodologies can be identified, as well as any potential issues and solutions. The following section describes three case studies, which have three different methods.

3.5.1. Kentucky

Kentucky Transportation Cabinet sponsored an Analysis of Traffic Growth Rates (KTC 2001), with primary objectives to determine patterns of traffic flow and develop traffic growth rates by traffic composition and highway type for Kentucky's system of highways. The study was carried out to

- conduct a literature search to determine if there were new procedures being used to more accurately represent traffic growth rates,
- develop a random sampling procedure for collecting traffic count data on local roads and streets,
- develop methods to predict vehicle miles traveled based on socioeconomic data,
- develop a procedure for explaining the relationship and magnitude of traffic volumes on routes functionally classified as collectors and locals, and
- develop county-level growth rates based on procedures to estimate or model trends in vehicle miles traveled and average daily traffic.

The study found no new approaches that could be directly applied to the predictions of growth rates in Kentucky; the survey of states indicated that historical data and regression analysis were most often used to predict growth rates.

With mixed results, the study developed models to predict traffic growth (VMT) for interstate and non-interstate travel in each of the 120 counties. Socioeconomic data are independent variables, including population, earnings, employment, per capita income, retail sales, and number of licensed drivers. The models were evaluated on two sets of measures:

- model diagnostic tests on the inputs and outputs
- relative prediction errors should be less than 10 percent for each county.

Additionally, yearly VMT growth rates should be within general ranges based on historical trends—1-6% for non-interstate and 2-4% for interstate VMT growth.

Two modeling methods were used: linear regression and neural networks. In the linear regressions, two modeling approaches were adopted:

- models were developed at the county level
- models were developed at the state level and then statewide VMT were apportioned to each county based on socioeconomic variables at the county level.

Efforts were also undertaken to minimize multicollinearity through reduced models and transforming dependent and independent variables into logarithmic forms. A time variable was also included in the model testing to account for possible changes in driving and travel trends over time. K factors approach was also tested to account for missing variables.

Neural network (NNets) modeling was conducted in a few trials. NNets are computational structures capable of learning from examples and quickly recognizing the patterns they have learned. Learning (or training) and recognition are the two fundamental modes in which NNets operate. Specifically, the Backpropagation Neural Network was developed through a two-level training and testing process:

- In the first level, an NNet was developed and tested on the entire database and the residuals were retained and treated as an independent variable in the second level.
- In the second level, another independent NNet was developed on the 1993-1997 data and then tested on the 1998-1999 data.

The variables used in the non-interstate NNet-K model include:

- LN Urban mileage
- LN Population
- LN Employment
- LN Earnings
- LN number of Interstate Interchanges
- LN number of Parkway interchanges
- Residual (K-Factor)

Results from linear regression modeling efforts are summarized as follows:

- Development of county groups for modeling purpose was unsuccessful.

- County-level regression models have very high R^2 but high errors as well for many observations (county/year combination). They were deemed inadequate to predict VMT at the county level.
- State-based regression models are time-series-based and perform better than county-based regression models but still do not have adequate predictive errors at the county level.
- Reduced models and models with transformed variables are acceptable at the statistical goodness-of-fit level but unacceptable in terms of prediction accuracy criteria at the county level.
- Corridor-based regression models do not have adequate predictive power as judged in terms of R^2.

The final models include:

- A non-interstate NNet Model with K factors, which produces results that meet the predictive accuracy threshold with exception of one county, although predicted values for a number of observations deviate from the "normal" range.
- An interstate VMT regression model with K factors, which produce much better results than other regression models, with approximately 85% of the observations within the predictive accuracy threshold.

Both models have generated VMT prediction values that are well beyond the normal range.

Examination of VMT data shows that

- Significant proportions of yearly VMT changes are well beyond the normal range —1-6% for non-interstate and 2-4% for interstate VMT growth— 47% for non-interstate VMT and 75% of interstate VMT.
- The relationship between change in interstate VMT and socioeconomic variables is weak at the corridor level.

3.5.2. Indiana

INDOT sponsored a study to develop unbiased statewide VMT estimates for personal and commercial travel (Friker and Kumapley 2002). The study tested three methods—licensed driver-based, household-based, and fuel-tax-based. These methods are all based on socioeconomic data.

The first two are survey-based cross-classification models based on licensed driver and household travel characteristics, using data from the Nationwide Personal Transportation Survey (NPTS). These models are intended to address the problems of sampling bias associated with current VMT estimation procedures. Variables in these models include average annual miles driven per licensed driver, by sex and age cohort, and average annual household VMT based on selected demographic and socioeconomic characteristics.

The licensed driver-based method estimates and forecasts short-term and long-term statewide VMT. Total state population estimates and projections were obtained from the Census Bureau for years from 1990 through 2010, as well as population by sex and population eligible to drive (aged 16 years and older) by sex. License driver by sex and age cohorts were extracted from the Highway Statistics for the years 1994 through 2000. The population of licensed drivers was projected for the years 2000 through 2010, based on the average percentage of the licensed driver ratio to the percentage of the state population eligible to drive, over the1994-2000 period. The statewide VMT estimates were conducted in three steps:

- Total licensed driver population was estimated for a subject year.
- The licensed driver population was distributed by sex and age groups, based on historical distribution.
- Annual VMT for all licensed drivers by sex and age cohorts were calculated based on average annual VMT per licensed driver, by sex and age cohorts, which was derived from 1990 and 1995 NPTS surveys.

The household-based method estimates statewide personal travel VMT based on three socioeconomic variables—income groups, household size, and vehicle ownership by area types. The average annual household VMT was estimated for the three sets of cross-tabulations, using the 1995 NPTS. Area types were defined as three categories—rural, light urban, and dense urban—an aggregation of NPTS's original five categories. The statewide VMT was estimated in the following three steps:

- Input the number of households in the study area for each cell of the VMT estimation matrix – by area type and socioeconomic characteristics
- Multiply the number of households by the estimates of nationwide average annual household VMT for each cell
- Aggregate estimates of total household miles within each cell to obtain the VMT.

Data for commercial truck travel includes IFTA and MCFT databases. The IFTA and MCFT require the carriers to report the total annual miles traveled by all qualified vehicles for tax estimation purposes. These annual miles represent total Indiana commercial vehicle VMT and were adopted in this study for the estimation of commercial vehicle VMT. Data on total truck activity by fuel type for the 58 jurisdictions were obtained from the Indiana Department of Revenue for the period 1999 though 2001. The total miles driven by all vehicles from all jurisdictions, for all fuel types, are taken as the interstate commercial vehicle component of Indiana VMT. The Indiana Motor Carriers Fuel Tax License (MCFT) is required by all Indiana based carriers whose activities are entirely within the state. All intrastate carriers in Indiana report their quarterly tax returns to the Motor Carrier Services Division of the Indiana Department of Revenue. Data on total truck activity by fuel type for all intrastate vehicles were obtained from the Indiana DOR for the period 1999 though 2001. The total miles driven by all vehicles for all fuel types are taken as the intrastate commercial vehicle component of Indiana VMT.

As a result of the study, a licensed driver-based method was recommended for the estimation of statewide personal travel VMT.

Some problems were identified in the travel survey based VMT methods, including:

- Licensed driver data from two sources—the Indiana Bureau of Motor Vehicles and the Highway Statistics—are inconsistent and differ significantly. These discrepancies may affect the accuracy of the VMT estimates.
- The 1995 NPTS provides odometer-recorded and self-reported vehicle mileages, which were found to be significantly different from each other. The reliability of both data items was questionable.
- The NPTS data does not represent commercial vehicle travel.
- None of the three methods produce VMT estimates by highway functional classes, and the statewide VMT estimates can be used as control totals for planning purposes.

3.5.3. Oregon

In July 2000, Oregon Department of Transportation (ODOT) completed a Statewide Vehicle Miles of Travel Study (Statewide VMT Study). The purpose of the study was to evaluate ODOT's existing procedures for estimating statewide VMT and to create a single unified procedure for estimating statewide VMT. As documented in the Statewide VMT Study, three different sections within the ODOT estimate statewide VMT for various purposes, including strategic planning, identifying transportation system improvement needs, allocating highway funds and determining user taxes/fees, and evaluating crash statistics.

The Transportation Data and Policy Sections of the Transportation Development Division and the Financial and Economic Analysis Section of the Central Services Division each used a different procedure to estimate statewide VMT. The Transportation Data Section used the traffic-count based procedures to estimate VMT. The data include Highway Performance Monitoring System (HPMS) and the Traffic Monitoring System databases. The HPMS is prepared in accordance with the FHWA procedures. VMT estimation was conducted at the system-wide level, by functional class, by vehicle class, and by jurisdictional class. Adjustment and growth factors were used in the estimation process.

To forecast state tax revenues, the ODOT Financial and Economic Analysis Section adopted a fuel-based approach to estimating and forecasting VMT. ODOT prepared short-range (6-year) VMT forecasts every six months and long-range (25-year) forecasts every tow years. Long-range forecasts were also used to support long range planning efforts including the Oregon Highway Plan. Total VMT is divided into three categories— Light vehicle VMT, Medium-Heavy Vehicle VMT, and Heavy Vehicle VMT. For the first two categories, ODOT uses monthly fuel consumption data, fuel refund claims, and national miles-per-gallon estimates to calculate VMT. For heavy vehicles, VMT is estimated using actual reported mileage from weight-mile tax records and adjustment factors.

Three existing and two potential statewide VMT estimation procedures were evaluated based on the following ten criteria:

Accuracy

1. Accuracy of statewide VMT estimate
2. Accuracy of SHS VMT estimate
3. Accuracy of non-SHS VMT estimate

4. Information by roadway class, jurisdictional class, and vehicle type
5. Not subject to year-to-year statistical or methodological fluctuations
6. Not subject to increasing error over time

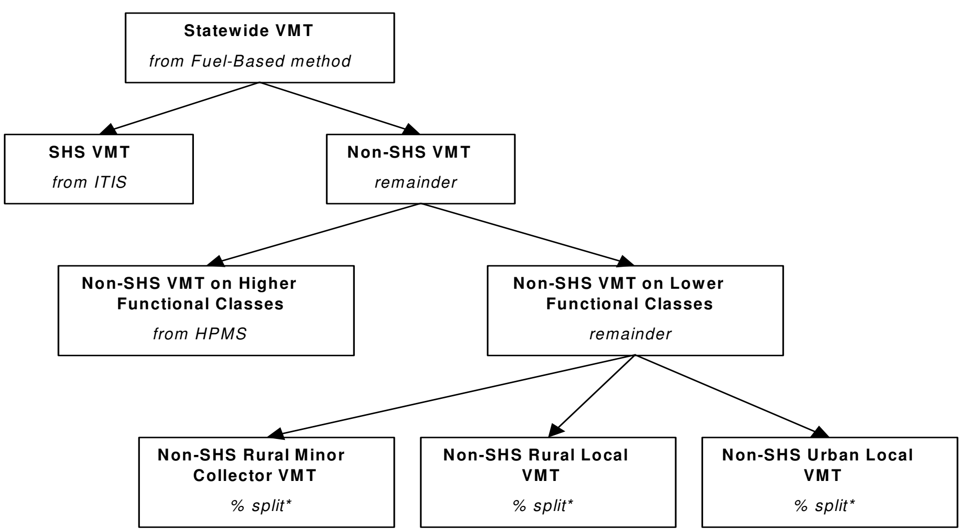
Consistency

7. Consistency of methodology across roadway classes
8. Consistency in direction and magnitude with published Federal VMT estimates
9. Consistency with revenue forecasts

Required Resources and Information Availability

10. Ease of data collection and calculations

Based on the evaluation and a survey of five states, the study made a general recommendation for purposes other than HPMS submittal and a HPMS submittal specific recommendation. The general recommendation includes using the fuel-based method to estimate overall statewide VMT, and then disaggregating this overall VMT into functional classes based on data from the Integrated Transportation Information System (ITIS), HPMS and ODOT's Supplemental Count process (see Figure 3-1). The HPMS submittal specific recommendation consists of two options: status quo and the fuel-based+HPMS method. For the second option, the fuel-based method is used to estimate statewide VMT. Then, the HPMS VMT estimate for the higher functional classes is subtracted from the statewide VMT to obtain the VMT estimate for the lower functional classes, which is later allocated to the rural minor collector, rural local and urban local classes using percentage splits.



* Percentage split derived by taking moving averages of the data from ODOT's Supplemental Count Program.

Figure 3-1. General Recommendation for Estimating Statewide VMT and Allocating to Functional Classes
Sources: David Evans and Associates. 2001. Issues and Implications of Implementing the General Recommendation from the July 2000 Statewide Vehicle Miles of Travel (VMT) Study. "White Paper" Prepared for Oregon Department of Transportation.

While the general recommendation has its advantages, it also has some limitations (see Table 3-3).

Table 3-3. Pros and Cons of the General Recommendation

Pros	Cons
• Fuel-based method for estimating overall statewide VMT produces the most consistent VMT forecasts • Allows for the disaggregation of overall statewide VMT into functional classes consistent with federal HPMS classifications. • Estimated VMT is consistent with forecast revenues since it is part of revenue forecasting process • Effective method for long-term forecasts • Heavy vehicle VMT based on actual reported mileage from weight-mile tax records rather than estimation • Unifies the existing VMT estimation procedures adopted by different ODOT divisions into one procedure	• National mpg estimate reflects the average fuel economy of the national fleet and may not represent the average fuel economy of the Oregon fleet. Method is very dependent on having an accurate breakdown of the vehicle fleet. • Method does not adjust for the net import/export of fuel • Weak method for estimating medium-heavy vehicle fuel economy • Unclear how to account for growth in the use of alternative fuel vehicles • Accuracy is dependent upon data collection performed by other agencies

Source: David Evans and Associates. 2001.

Task 1: Decide traffic count locations and put data in the network

3.6. Review of PENNDOT and MPO Travel Data

PENNDOT's TIS/RMS system and available MPO travel demand models can provide key data needed for the development of a statewide travel forecasting system. This section provides potential PENNDOT and MPO data items that can be utilized in the development of the forecasting model framework options discussed in previous sections. Table 3-4 provides an overview of the use of available data sources in potential forecasting components.

Table 3-4. Potential Role of PENNDOT and MPO Travel Data

Potential Forecasting Component	PENNDOT/MPO Data Sources
Estimating Total Trips	MPO Population & Employment Forecasts
Estimating Trip Lengths	MPO Population & Employment Densities; MPO Travel Demand Model External Travel Shares
Estimating Share of Trips by Auto	MPO Travel Demand Model Transit Shares
Estimating Share of Trips by Roadway Type	MPO Travel Model Future Year Network Lane Miles by Roadway Type
Validation Cross Checks	TIS Trended Annual Growth Factors; HPMS Trended VMT; MPO Travel Demand Model Future Year VMT

Much of the data available from the PENNDOT TIS/RMS/HPMS systems are reasonable for updating traffic volumes and VMT to the current year or for understanding past trends of travel growth. However, these rates are not necessarily sufficient for estimating future forces behind traffic growth. As a result, the PENNDOT data will most likely serve as important cross checks to the growths produced by the completed forecasting system. These cross checks will provide the user with important information and insights into the potential fluctuation of projected growth rates based on the available data sources and methodologies.

MPO travel demand model input and output data may serve multiple roles in the forecasting system. The output VMT from travel demand model can also serve as an important cross check of growth rates. In contrast, the socioeconomic (population, households, employment) forecasts, densities, external travel percentages, transit mode shares, and network lane miles may be direct inputs to the forecasting model equations and analyses.

An overview of the available PENNDOT and MPO travel data, pertinent to the potential forecasting system, is discussed in the following sections.

3.6.1. Overview of PENNDOT Traffic Monitoring System

PENNDOT's Traffic Monitoring System (TMS) provides the coordination tool needed for managing the traffic data collection activities within Pennsylvania. The system is made up of several key components that provide valuable information needed for understanding the past and current level of travel throughout the state. Nearly 6,500 counts are conducted annually and uploaded to the Traffic Information System (TIS) and Roadway Management System (RMS). Figure 3-2 summarizes the interrelationships between each of the system components.

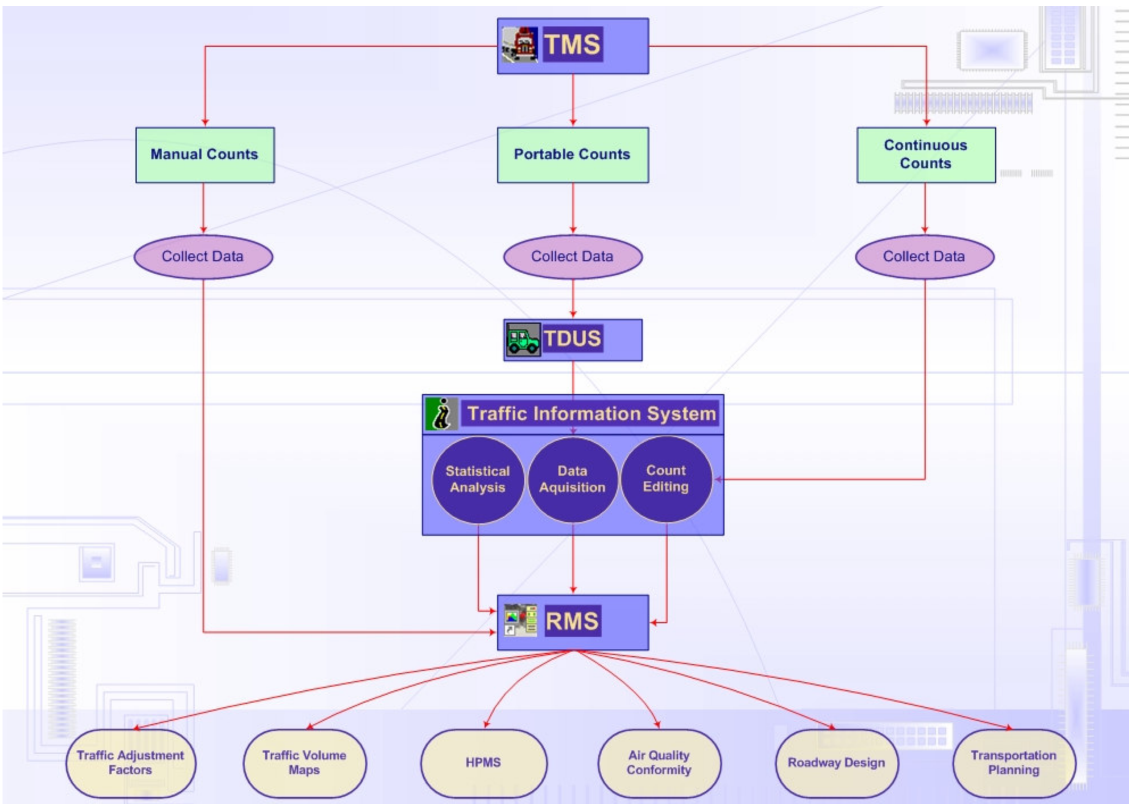


Figure 3-2. The PENNDOT Traffic Monitoring System

Source: PENNDOT

TIS: In 2002, the BPR implemented the computer-based TIS, which consolidates existing functions from different count programs into a modular, integrated environment. It can exchange data with existing systems such as the RMS and the GIS. The TIS allows users to edit continuous count data, calculate traffic adjustment factors, and produce summary data reports. A statistical analysis module uses the entire traffic database to generate traffic volume growth and adjustment factors (e.g. annual growth rates by functional group, seasonal adjustment factors) that can provide a valuable resource for calculating past traffic growth trends throughout the state. Pertinent features include:

- *Growth Factor Estimation.* The system uses a least-squares approach for determining average traffic growth factors for various functional/geographic groups of sites.
- *Seasonal Variation Factors.* The system helps users maintain a system-wide set of seasonal variation factors, based on continuous counts, for use in processing short-term counts.
- *Data Mining.* The system includes other statistical functions to support ad-hoc queries and analyses.

RMS: The Roadway Management System (RMS) is a highly evolved database for storing vast amounts of information on Pennsylvania's large highway network. This system was implemented in 1985 and has become substantially larger since that time. RMS provides a “snapshot” of the current estimated traffic volumes and physical characteristics by route segment for all state roadways in Pennsylvania (limited local coverage). This system maintains over 700 variables of information on each segment of highway. Typically in addition to physical condition, the maintenance planner uses highway geometry, pavement type, network designation, right-of-way, traffic volumes, maintenance history, etc. to support the rehabilitation strategies and work activities to be performed. In addition, RMS data serves as a valuable resource for air quality inventory and conformity calculations, Highway Performance Monitoring System (HPMS) VMT calculations, and other planning and design activities. The RMS database source can serve as a primary base (providing an estimate of roadway mileage) from which to compute future growth rates for VMT. Key traffic information contained in the database includes:

- Roadway functional class, urban/rural code, and county
- AADT traffic volume
- Roadway distance

The RMS-based HPMS VMT will play an important role in determining past trends in VMT and for performing future year VMT trend analyses. VMT is not only a function of volume growth but also with changing roadway mileage, travel patterns, and other travel characteristics.

3.6.2. Overview of PENNDOT Trend Factors

PENNDOT’s Bureau of Planning and Research (BPR) has been preparing annual traffic reports since 1990, which include reported “System-wide Global Update Factors” or “Trend Factors”. These factors are average annual growth percentages for each county, functional class combination in the state.

Before 1998, “global update” factors were developed from permanent ATR locations (approximately 63 locations, which have been in existence for over 20 years) and close to 1,000 raw counts representing a 4-5 year period. Raw counts were examined and processed to create a trend factor. The process was difficult and rarely yielded clear trends. PENNDOT determined that counts, even at the same location, were very inconsistent from year to year due to the variability of the day, month and season in which the counts were taken (even if adjusted). Offline “smoothing processes” were conducted by PENNDOT to account for these problems and to produce the “global update” factors.

In 1998, the BPR stopped the above process and implemented a system using 250 permanent ATR sites that collect 7-day counts 3 times a year for analysis. These counts are now used to develop the current "global update factors" for each county, functional class grouping. Sample size presents a challenge when data is desired by each of 67 counties and/or 4-5 functional classes.

Recent PENNDOT research projects regarding the traffic data processes found that sufficient sample sizes were not being collected. In 2002, the BPR implemented TIS to consolidate existing functions from different count programs into a modular, integrated environment. PENNDOT now uses the TIS-based annual growth factors to estimate current ADT for total vehicles and trucks for count locations where the count is older than the current year. The growth factors that are estimated and used are based on Traffic Pattern Group (TPG). In PENNDOT's Road Management System (RMS), trend factors by County/Functional Class (FCG) are used to produce the current year traffic volume estimates, and these trend factors are derived by a linear regression analysis of historical data.

3.6.3. Role / Limitations of PENNDOT Traffic Data for Forecasting

As indicated in Table 3-5, the historical count data and trend factors within the TIS system in combination with the RMS traffic database and HPMS VMT are useful for identifying past patterns and trends in VMT and traffic volume growth for the state-owned roadways. They account for variations in traffic growth by county and by the functional class of the roadway. While the methods used by PENNDOT are reasonable for updating traffic volumes and VMT to the current year, these rates are not necessarily sufficient for estimating future forces behind traffic growth. Historic trends are a significant factor to consider, but is not responsive to changing conditions.

Although trend factors, RMS data, and HPMS VMT have limitations, they have played an important role in estimating future VMT for air quality inventory and conformity purposes due to the lack of other available data sources. Trend analyses have been conducted on the "global update" factors and HPMS VMT. These relationships have been used to forecast future volume growth for different county, functional class groupings throughout the state. The growth rates have then been applied to the base year RMS traffic volumes to estimate future year VMT. The VMT estimates have been used in air quality inventories and for conformity analyses in many counties. However, the future forecasts are not used for conformity analyses in areas with travel demand models. The travel demand models incorporate socioeconomic and land use factors into the estimation process, which provides a theoretically more enhanced approach.

The forecasted growth rates are updated each year as new HPMS VMT and "global update" factors are developed by the BPR. In general, the use of these growth rates has provided conservative estimates of future VMT that actually have corresponded closer to reported HPMS VMT growth than the growth produced by travel demand models in that same time frame. For emission inventory development, this is an important issue since an underestimation of future VMT and emissions may cause conformity and regional attainment problems due to unrealistic emission budgets (targets) and the lack of necessary regional control strategies implemented to offset such growth. The consultant's past experience with travel demand models in Pennsylvania has shown that models generally produce lower growth rates than what has been shown in HPMS over the last 10 years. Due to air quality regulations that require consistency with HPMS, the choice and application of future growth rates is an important issue. Likewise, underestimation or overestimation of future growth can also have implications on regional corridor studies and design alternatives. Such issues can result in both deficiencies and excess of planned roadway capacity improvements to account for future travel.

Table 3-5. PENNDOT Traffic Data's Use in Forecasting

PENNDOT Data Item	Primary Use	Limitations	Vision of Use in Travel Forecasting
Historical Count Data	Understanding past volume growth trends	May produce inconsistent results; may not directly relate to VMT	None due to existence of Trend Factors
Trend Factors	Understanding past volume growth trends	Does not directly relate to VMT; statistical significance for individual counties; generally do not indicate a decline in travel for any region in PA	Perform trend analysis to estimate future volume growth rates; Apply to current RMS database to estimate future VMT; Utilize as cross checks for forecasting system
RMS Database	Static database used for producing annual HPMS VMT; Provides source or current roadway mileage	Does not contain information useful for identifying past or future trends	Used as base roadway mileage for computing VMT estimates
HPMS VMT	Understanding past VMT growth trends	Local VMT estimates based on offline estimation process	Perform trend analysis to estimate future volume growth rates; Apply to current RMS database to estimate future VMT ; Utilize as cross checks for forecasting system

Due to the importance of producing realistic estimates of travel and VMT growth, it is recommended that historical trend factors and HPMS VMT be examined, trended to future years, and used as cross checks to the values produced from the completed forecasting system. The historical rates may not have produced accurate results for individual years but have generally produced acceptable results over a 10-year time frame. As a result, these tabulations should be produced for informational or comparison purposes.

Additional investigations will be needed to assess what aggregation level is appropriate for producing forecast HPMS and volume growth rates based on the historic values. At a minimum trended growth rate equations should be developed for the following aggregations:

- Urban Interstate
- Urban Non-Interstate
- Rural Interstate
- Rural Non-Interstate

3.6.4. Role of MPO Travel Demand Model Data for Forecasting

The historic trends determined from the PENNDOT data are a significant factor to consider in developing and validating future year growth rates, but they alone are not responsive to changing conditions. Many urban MPOs have other data resources that can serve as valuable inputs and cross checks to a statewide forecasting system. Such data includes the regional travel demand models and socioeconomic forecasts used by the MPOs for regional and long-range transportation planning.

Travel demand models utilize input socioeconomic information (e.g. population, households, and employment) for predefined traffic analysis zones within the travel demand model coverage to estimate future travel on the regional roadways. Travel demand models offer several distinct advantages over simple trending analyses:

- Forecasts based on amount and location of population and employment
- Socioeconomic inputs produced by MPO based on the latest information on planned developments
- Future year runs utilize highway networks with planned projects
- Travel demand model distributes trips based on location of housing and jobs
- Travel demand model estimates diversions based on increased traffic levels and roadway enhancements

As illustrated in Figure 3-3, there are currently 20 Pennsylvania counties covered by travel demand models with additional 5 counties to be covered within the next several years. Each travel demand model covers the majority of state-owned roadways as well as some local and township roads. Many of the MPOs have recently conducted, or will in the near future, updates to the travel demand model inputs based on 2000 CENSUS information and updates to socioeconomic forecasts. Each of the regional models is used for air quality analyses; and as a result, future year networks and scenarios are produced based on the planned projects contained in the region's Transportation Improvement Program (TIP) and Long-Range Plan (LRP).

Although travel demand models are considered a robust tool for analyzing future traffic growth and project impacts, they also have limitations. Travel demand models account for the location of housing and jobs and the potential impact of planned project improvements on diversions; however, the model does not accurately capture the many other changing variables that have a significant impact on VMT. These include the status of the economy, fluctuating gas prices, and changing travel behavior. Most of the travel demand models base trip making on the forecasted number of households and the average number of persons per household (based on the supplied forecasted population). These values are used to access trip production lookup tables to determine the number and type of trips being made by each household. Based on the consultant's experience in utilizing travel demand models throughout the state, the travel demand models have generally produced less travel growth than that shown in the HPMS VMT through the 1990-2000 timeframe. The reasons for the differences are many, and some of these will be discussed in Chapter 6.

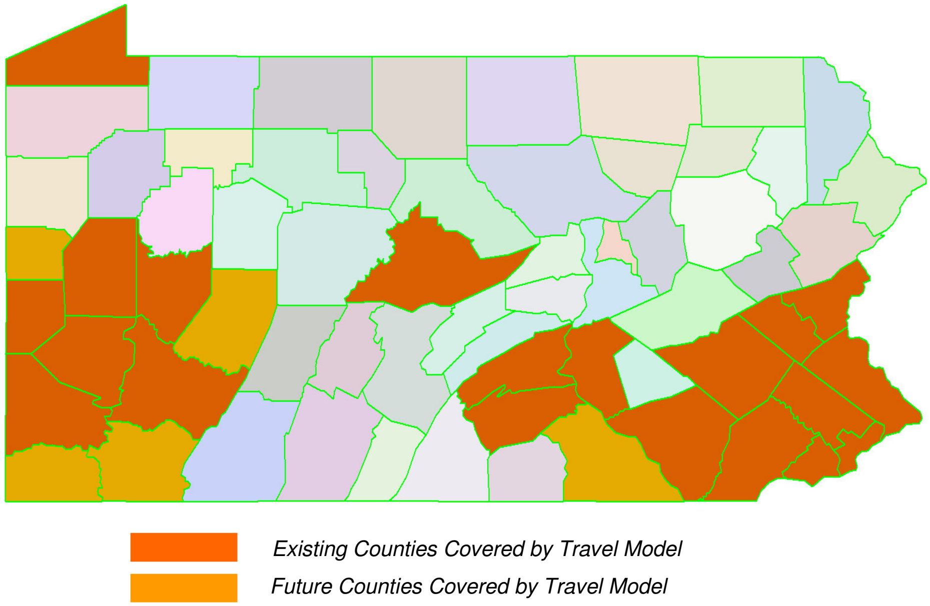


Figure 3-3. Pennsylvania Travel Demand Model Coverage

MPO travel demand model input and output data may serve multiple roles in the forecasting system. These roles range from utilizing the socioeconomic forecasts as direct inputs to the forecasting methodology to using the output future year VMT estimates as a cross checks to the forecasting process growth rates. As illustrated in Figure 3-4, the primary MPO travel data items with potential use in the forecasting process are the following:

- Socioeconomic (Population, Households, Employment) Forecasts and Densities
- Future Roadway Mileage by Roadway Class (Freeway/Non-Freeway)
- Future Transit / Non-Auto Trip Shares
- Future VMT by Roadway Class and External Travel Share

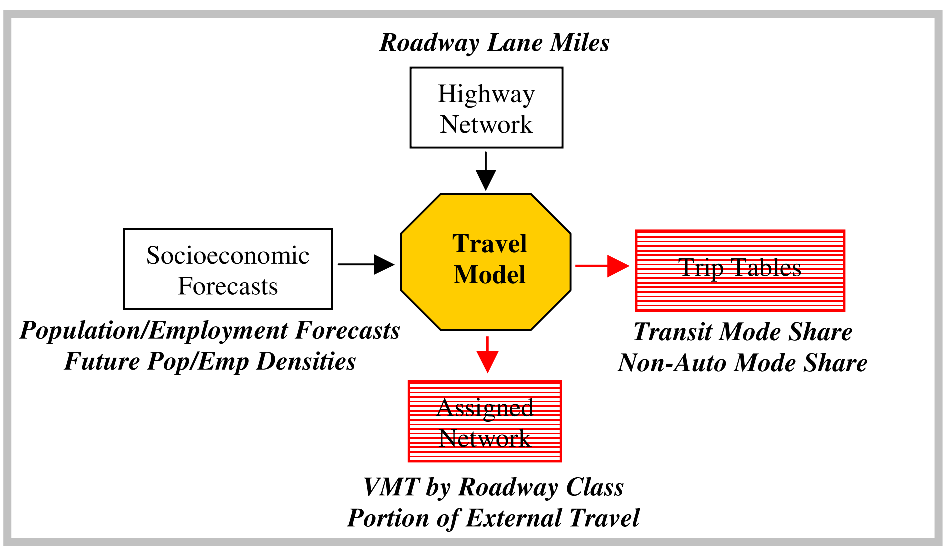


Figure 3-4. MPO Travel Demand Model Data

There are several options for incorporating travel demand model data into the forecasting process. Three potential options are discussed below.

Option 1 – Utilize MPO Travel Demand Model Output VMT as a Cross Check. This potential option is illustrated in Figure 3-5 and involves utilizing the travel demand model outputs directly to obtain future VMT growth factors for county, roadway class (freeway, non-freeway) combinations. These growth rates can be used to cross check or validate the growth rates from the PENNDOT forecasting system. In this option, MPO data is not specifically used in the PENNDOT forecasting process and is simply used as a comparison. Alternatively, the MPO model growth rates can be used in combination with the PENNDOT forecast growth rates to create a composite or average growth rate as discussed in the following section.

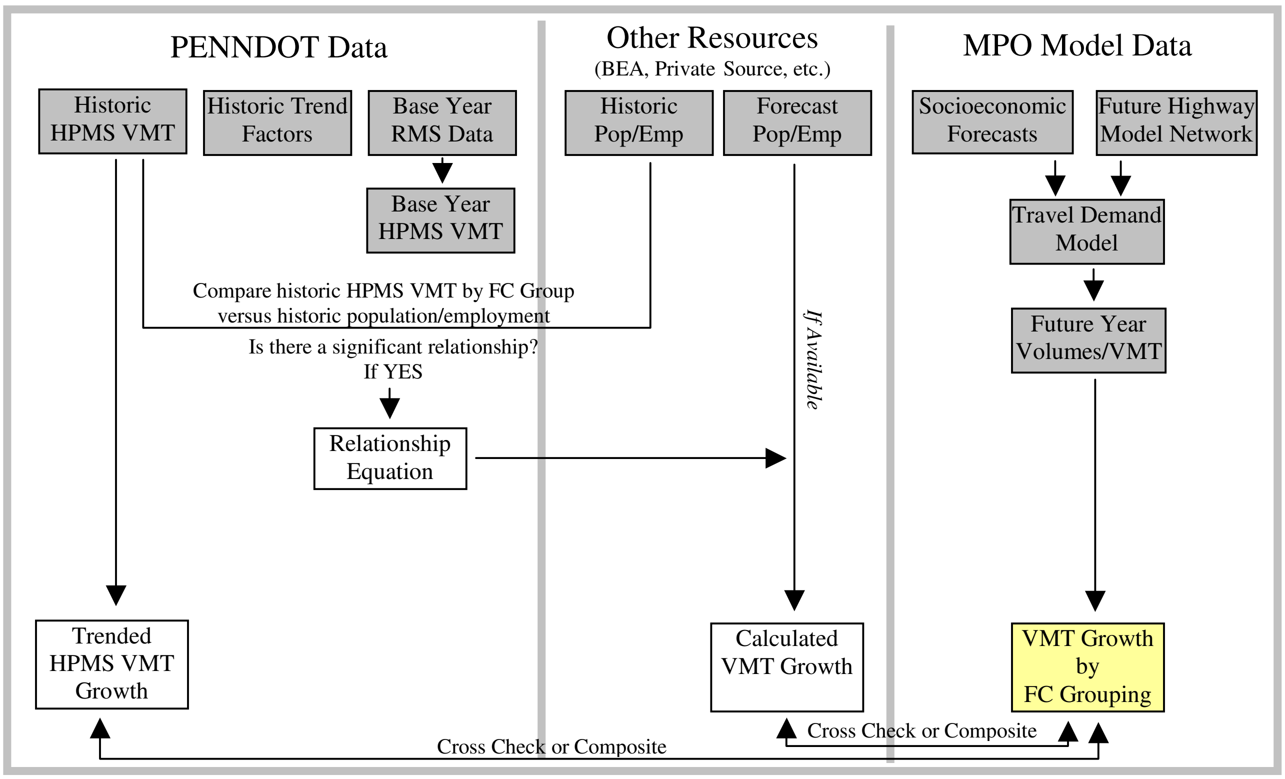


Figure 3-5. Utilize MPO Travel Demand Model Output VMT as a Cross Check

This methodology requires a complete travel demand model run for future year scenarios. However, since all travel demand model areas are non-attainment areas, it can be expected that future scenario runs with planned projects will be produced and summarized for each conformity analysis. The growth rates can be compared to trended HPMS VMT and to growth determined from the forecasting process, which would use population/employment forecasts from other sources.

Utilizing the travel demand model outputs directly ensures that future VMT estimates account for diversions and changing roadway mileage based on the planned highway projects. In addition, the model would account for significant transit alternatives that have a significant impact on VMT.

Option 2 – Utilize MPO Travel Demand Model Socioeconomic Forecasts. A recommended enhancement to the PENNDOT forecasting system is the usage of available MPO socioeconomic forecasting data as direct input to the growth rate calculation process. Figure 3-6 illustrates the potential for integrating MPO socioeconomic forecasts into the forecasting process. For this case, the travel demand model outputs and highway network are <u>not</u> utilized in the development of growth rates. The use of MPO socioeconomic forecasts would not eliminate the need to first develop the statistical relationships between historic population and employment growth and VMT. Historical HPMS VMT totals by county and functional class group can be compiled and compared to historical population and employment estimates from either the Bureau of Economic Analysis or other state data sources (e.g. Penn State Data center or private sources) as will be determined through future research. The comparisons will involve computing statistical correlations to determine if there is an acceptable level of correlation between VMT and population/employment growth. It is anticipated that comparisons will be made for counties (or in some cases county groupings, or even statewide) and for four primary functional groups: Urban Interstate, Rural Interstate, Urban Non-Interstate, and Rural Non-Interstate. If population, employment, or both are correlated with HPMS VMT growth, then relationship factors (or elasticities) must be developed. If no correlation is determined between VMT growth and population or employment then alternative methodologies or procedures must be utilized.

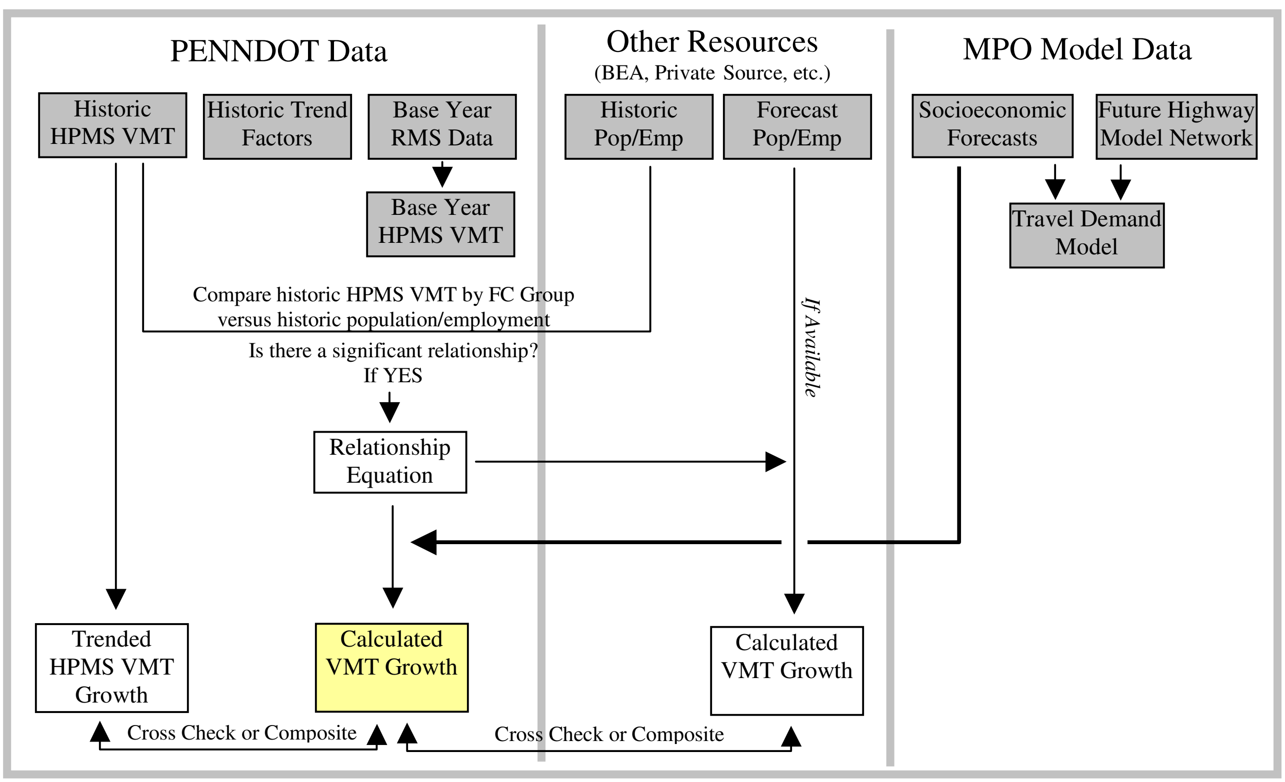


Figure 3-6. Utilizing MPO Socioeconomic Forecasts

This methodology supplements historical trend analysis with growth rates based on socioeconomic forecasts prepared by MPOs throughout the state. The analysis does not require travel demand model runs and simply uses the forecasted inputs to the model, which should be readily available. There are some limitations of this methodology. If there is no statistical significance between past population/employment and VMT growth, then it is difficult to determine the potential impact of forecasted data on VMT. In addition, this methodology does not directly account for future roadway mileage changes or significant diversions due to new roadway or capacity addition projects.

Option 3 – Utilize Additional Model Input and Output Data: This potential option builds upon Option 2 to create a greater level of integration of MPO travel demand model data. This option is highly dependent upon the design and components utilized in the planned PENNDOT forecasting procedure. The potential for creating a more robust statistical model to estimate future VMT growth may create the need for additional forecasting data including the following:

- *Population/Employment Densities* – This data may be used to estimate potential changes to regional average trip lengths. Such a change, even without a change in trips, could result in changes to forecast VMT. Densities can be computed from the travel demand model socioeconomic inputs in combination with county or zonal areas (e.g. square miles of county).
- *External Travel Percentage* – External travel may impact future average trip lengths in each region. Travel demand model forecasts of external travel may be extracted from the assigned model network output files for use in the forecasting procedure.
- *Transit and Non-Auto Shares* – Large-level transit or transportation demand management projects can have a significant impact on regional VMT. Typically these impacts may not be accounted for in a non-model forecasting process. If statistical models are utilizing that incorporate such data, the information can be extracted from the travel demand models used in the state. Most of the MPO travel demand models estimate person travel and contain a transit module. The information is contained in the output trip tables.
- *VMT by Roadway Class* – The statistical forecasting models may base forecasting on aggregate area and roadway classes. As a result, future shares of VMT by roadway type may be a useful input in creating separate growth rates by several aggregate roadway classes. VMT by roadway class can be determined from the output assigned model network.
- *Lane Miles by Roadway Type* – Understanding the potential changes to the transportation system may be an element to creating statistical models to estimate future growth rates. Typically changes to lane miles will result from new construction of roadways. Although, such changes may be limited for many counties, some counties may experience high levels of growth due to induced land use created by new freeways in the region. The future year input travel demand model highway networks can be processed to obtain changes to lane miles for various roadway types.

The recommended forecasting process will most likely not involve all of the above variables; however, the MPO travel demand model data does provide an array of data that may be useful depending on the chosen options.

3.6.5. Utilizing and Interpreting Multiple Sets of Growth Rates

This section has provided an overview of the potential PENNDOT and MPO data sources that can be integrated to the forecasting system. Several of the key data items, including trended HPMS VMT, trended PENNDOT annual growth factors, and MPO travel demand model output VMT, are expected to serve as cross-check validation values. Due to the inconsistencies and differences between various forecasting methodologies, it is suggested that alternative growth scenarios from these sources be reviewed and possibly output along with the calculated growth rates from the developed forecasting process. The alternative growth rates in combination with the forecasted rates may be referred to as a low, medium, and high growth option. Alternatively, a composite growth rate may be calculated representing an average condition. By reporting all available growth rates, the user can understand the potential fluctuation of traffic growth and choose a value consistent with the needs of the analysis.

3.7. Review of Socioeconomic Data and Forecasts

This section documents findings associated with Subtask 1.5 Socioeconomic Data and Forecast of the Statistical Evaluation of Projected Traffic Growth project. The objectives of this subtask are to define the socioeconomic database needed to support traffic growth forecasting and recommend procedures and data sources to obtain this information. This section starts with a brief discussion of model design, then describes a number of potential data vendors that can provide the data needed to construct the PENNDOT Forecasting System and drive its forecasts, and finally evaluates these vendors and makes some preliminary recommendations.

3.7.1. Socioeconomic Variables and Traffic Growth Forecasting

The development of a traffic forecasting system requires historical data to estimate a statistical relationship between vehicle miles traveled (VMT) and a set of variables that are expected to be the key drivers of VMT. In turn, forecasting VMT requires projections of the variables used to explain VMT.

The data used in the estimation of a statistical model explaining VMT depends in part on the extent of aggregation of VMT both geographically and by road type. The primary focus of our analysis is long-term, county level VMT projections by type of road.

VMT Forecasting: Passenger Travel

To create county-wide projections of VMT over a 20-25 year horizon for several classes of roads, we first must identify the key elements of a model explaining VMT by county by road type. The total private auto VMT in any county i, at time t, will depend, by definition, on the number of trips taken, the average length of trip, the share of trips that are by private auto, and the share of trips taken on each type of road. Different variables are likely to affect each one of these components:

- Total Trips in county i, road type j at time t: N_{ijt}
    - Population
    - Age distribution of the population
    - Employment

- Average Length of Trip: L_{ijt}
    - Population Density
    - Employment Density
    - Extent of commuting out of the county
    - Extent of shopping out of the county (Employment in Retail?)

- Share of Trips by Auto: S_{ijt}
    - Auto ownership
    - Income
    - Auto operating costs

- Gasoline costs
- Transit service measures

- Share of Trips by Type of Road: R_{ijt}
  - Lane miles of each road type

A multivariate model of VMT by road type by county could take the form of:

$$VMT_{ijt} = f(N_{ijt}, L_{ijt}, M_{ijt}, R_{ijt}) + e_{ij} + u_{ijt}$$

for each road type j. This formulation forces relationships between drivers and VMT to be the same across counties except for the intercept. This assumption can be completely relaxed, however, by estimating separate models for each county.

Once satisfactory statistical models of VMT have been constructed, projections of the drivers are needed to create the forecasts of VMT. It must be noted here that policy decisions regarding transportation investments that add to highway capacity will **directly** affect VMT, as described in the generic model above, and that they are also likely to affect VMT **indirectly** through their impacts on population and employment. It therefore would be useful to construct sub-models linking population and employment growth to lagged investment in highways. Armed with these sub-models, PENNDOT could undertake either static simulations of traffic growth, based on published projections of population and employment, or dynamic simulations incorporating the feedback of highway capacity expansion on population and employment.

As outlined above, a variety of data will be needed to build and forecast the PENNDOT county models. The historical data on VMT, lane miles by road type and other traffic data will come from the PENNDOT Traffic Information System. It should also be possible for PENNDOT to provide historical data on the number of licensed drivers and/or number of registered vehicles by type by county. A quick search on the Web indicates that data on the size of each Pennsylvania county (measured in square miles) is readily available, to compute population / employment densities.

The economic and demographic variables needed to construct and forecast the VMT models are available from a variety of sources, both public and private, as described in the next section. A preliminary list of candidate variables includes the following concepts:

- Population by gender and age distribution
- Number of households, household size
- Employment, total and by industry
- Personal income, total and all components (wages, non-wage income, transfer payments, …)
- Gasoline usage and gasoline price index
- Vehicle fuel efficiency
- Transit use for urban counties

All variables should be obtained for both the 67 individual Pennsylvania counties and the state as a whole. These time series data should be obtained annually, and for the longest historical time period possible. If a sufficient number of observations are available, the models can be estimated with a portion of the historical data, with the rest being used to test the simulation capabilities of the models.

VMT Forecasting: Freight

Freight traffic is driven, in part, by a different set of variables than passenger traffic. There are three separate components of freight VMT:

- Freight originating in PA that is either delivered locally or exported
- Freight imported into PA
- Freight originating outside of PA with final destinations outside PA

Each of these components of freight traffic is likely to be affected by different factors.

Freight that originates in PA will be affected by expected future growth in freight generating industries as well as the growth of PA counties such as warehousing centers. At the state level, data on Gross State Product by industrial sector are available so that aggregate projections for industries that generate significant motor freight can be made. Unfortunately, these data are not available generally at the county level, and if they were they would likely be of questionable reliability. As a substitute, detailed employment data by industry sector are available at the county level, and could be used to make projections of growth in sectors that generate significant freight VMT.

The amount of freight traffic with a destination in PA—whether originating within state or from out of state is likely to depend on a number of factors including:

- Growth in aggregate personal income
- Growth in industries requiring inputs shipped by truck
- Share of freight that uses highways rather than rail, water or air

Again, we could use detailed, county level employment to predict growth in industries requiring significant shipping of inputs by truck. Additionally, we could include the future availability of alternative shipping modes based upon expected investment (or disinvestment in the current rail infrastructure).

VMT associated with freight passing through Pennsylvania will be affected by a number of additional factors reflecting the economic growth in neighboring states as well as the projected growth of ports within state and ports in neighboring states. Thus, forecasts of freight that is passing through Pennsylvania might include data on:

- Projected tonnage of freight in the Philadelphia, Wilmington, and NY/NJ ports
- Economic growth in freight-producing sectors in neighboring states
- Identifications of counties along key cross-state routes.

3.7.2. Data Vendor Description

In this section we describe a number of potential data vendors that can provide the data needed to construct the PENNDOT Forecasting System and drive its forecasts. Using the Web and follow-up phone calls, we have identified four private data vendors and three government data sources. Each of these sources is described below. Contact information for all vendors is provided in an appendix to this report.

Using the preliminary model outline presented in Section 2, we developed a series of questions that were posed to each of the potential vendors. Those questions included:

- Name of vendor / agency providing data and forecasts, and basic information
    - Where located, how long in business?
- How are the forecasts prepared; that is, what sort of models underlie the forecasts
- What variables are available (employment, income, demographics, …)
- What is the data frequency (annual, quarterly, …)
- How often are the historical data and forecasts updated?
- How can the data be delivered to the client (hard copy, on disk or CD, on website with password to download)?
- What is data cost and conditions of sale
    - Can the client purchase just what is needed, or must they buy a package?
    - Must the client buy a subscription to gain access to the data?

The answers given by the vendors, or gleaned from their documentation are described below.

As noted above, we try to describe, in general terms, how each forecast vendor claims to prepare their forecasts. That information is important in that it represents one way to evaluate the potential “quality” of the forecast. To give the reader a better understanding of what those descriptions mean, and why it is important, a brief primer on regional modeling and forecasting is provided below.

In the regional modeling literature, models are commonly characterized as “Top-Down”, “Bottom-Up” or some hybrid of the two. Top-down and bottom-up models take essentially opposite approaches to modeling regional economic / demographic activity. A top-down regional model begins with a model and forecast for the nation and links the smaller region to it. For example, manufacturing employment in a particular state may be predicted as a function of U.S. manufacturing employment. Few modelers would attempt to link county manufacturing employment directly to the corresponding national concept, however. Instead, the county models may be linked to state, Census Region or Economic Area models, which would in turn be driven by a national model. Conversely, a bottom-up model would predict regional activity as a function of some set of strictly regional variables. The forecasts for larger regions are obtained by adding up the forecasts from the smaller regions.

Both approaches have pluses and minuses. The data at the national level is updated much more frequently than the data for smaller regions, so that top-down models incorporate more current information in their forecasts. By relying primarily on national data, however, top-down models ignore the important differences between different parts of the nation, which affects the relative rates of economic and demographic growth in those regions. Indeed, one criticism of top-down models is that they simply share out a national forecast adding little, if any region-specific information.

By reversing these arguments, one has the pros and cons of the bottom-up approach. There is relatively little data that is available for the states and counties in a timely fashion. Hence, models built from existing regional databases are at least a few years out of date. While bottom-up models are rich in regional detail, they ignore important variables like interest rates that are essentially determined in a national market.

Most regional forecasting models now employ a combination of these two basic approaches. These hybrid models use both national and regional variables, as appropriate, to predict regional activity. Some current models add linkages between regions, using local unemployment rates to drive intra-regional migration and population growth. The new models represent an evolutionary change from the top-down / bottom-up models of the past. They are in response to increased demand from both the private and public sectors for more accurate models and forecasts for smaller and smaller geographies.

U.S. Census Bureau, and Bureau of Economic Analysis

The Census Bureau and Bureau of Economic Analysis (BEA) are both branches of the U.S. Department of Commerce.

The Census is the principle source of demographic information for the nation. For historical data, the Census is unparalleled, with all of the Census 2000 data online in a variety of data formats (Excel, PDF, CSV), that can be downloaded free of charge. The 1990 data is also available online and in similar formats. Similarly, the BEA is the primary source for county-level employment, wages and personal income data. The employment and wage data can be obtained online, at various levels of industry detail, and is available in both the SIC and NAICS industry classifications.

Some of the historical Census data may be quite useful in designing the PENNDOT Modeling System, in particular the Census 2000 Journey To Work database. These data describe the flows of people from their county of residence to the county in which they work. Hence, the data provide an initial approximation of what traffic flows between counties look like. The same is true for the BEA employment data, which could be used to identify major employment centers by county, reinforcing the information obtained from the journey to work database.

To the extent that employment and population centers exist in peripheral parts of the state, it may also be useful to gather some general demographic and economic data for the states surrounding Pennsylvania to gauge traffic flows across state lines. This would entail gathering data for the boundary counties in New York, New Jersey, Delaware, Maryland, West Virginia and Ohio.

For forecasting purposes, however, the Census and BEA can provide relatively little help for the PENNDOT project. The BEA only provides historical data, while the Census only produces demographic forecasts at the state and national level. One potential use of the Census forecast for Pennsylvania would be as a check on any other population / household forecast used to drive the PENNDOT model.

U.S. Department of Energy

The U.S. Department of Energy (DOE) produces an annual report, the Annual Energy Outlook, which provides analysis and long-term forecasts of energy use by energy type and consumer group. The current outlook extends through 2025. In particular, it includes three forecasts of oil prices – a baseline with high and low alternatives – that can be used to project gasoline and diesel prices for the PENNDOT VMT models. The DOE should also be able to provide historical data on gasoline / diesel usage and on vehicle fuel efficiencies, if these data are not available from PENNDOT.

All of these data are available for download from the DOE website.

Woods & Poole Economics Inc.

Woods & Poole is an independent firm that specializes in county-level forecasts. The company has been in operation since 1983, and is located in the Washington, D.C. area.

The Woods & Poole county economic and demographic projections are prepared using a “Top-Down” approach. They begin with detailed forecasts of U.S. economic and demographic variables, and use them to predict the same or similar concepts for 172 “Economic Areas” (EA), as defined by the Bureau of Economic Analysis (BEA). The EA’s are aggregates of contiguous counties that attempt to measure cohesive economic regions in the U.S. The EA forecasts are then used to drive their individual county forecasts. In the marketing literature on the Woods & Poole website, the company claims that the average absolute percent error for their 10 year county population projections is 10.2%.

Woods & Poole offers a variety of data / forecast packages. For the present purposes, the appropriate choice would be their “State Profile”. The package includes historical data and forecasts by year from 1969 through 2025 for every county and MSA for one state. The State and U.S. totals are also included. Both history and forecast data have annual frequency. Variables for which historical and forecast data are provided include:

- Population by age (single year cohorts), gender and race
- Number of households, household size and households by income level for 11 income ranges
- Employment and earnings for 13 sectors (using SIC industry designations)
- Personal Income by component
- Retail Sales for 10 sectors
- Educational Attainment (history only)
- Labor force and unemployment (history only)
- Private Non-farm Establishments by size and industry (history only)

The current forecast horizon is 2025. Forecasts are updated annually. The current price of the State Profile package is $395 for a print volume and a CD-ROM containing all of the data tables in spreadsheet files. No ongoing subscription fee is required to purchase these data.

Global Insight

Global Insight was created by combining two of the largest economic and financial forecasting companies in the world - DRI (formerly Data Resources Inc.) and WEFA (formerly Wharton Econometric Forecasting Associates). The merged company originally operated as DRI•WEFA. It changed its name to Global Insight in October, 2002. In its different incarnations, Global Insight has been in operation for over 25 years. The forecasting center is based in Eddystone, Pennsylvania.

County-level forecasts are produced by the company's U.S. Regional Service. Like Woods & Poole, the county forecasts are generated from a "Top-Down" modeling system. Global Insight starts with their U.S. macroeconomic forecast, and uses it to drive long-term state and MSA forecasts. Those, in turn, are used to generate the county forecasts. Both history and forecast data have annual frequency. The concepts forecast include:

- Employment for 9 industry sectors (using NAICS industry designations)
- Wage and salary disbursements and nonwage income, in both real and nominal terms, and average annual wage for nonfarm employment.
- Personal income, per capita and per household income, in both real and nominal terms
- Population, total and by age cohort for eight cohorts
- Number of households, total and by age cohort for six cohorts

The current long-term county forecasts extend to 2029. The forecasts are updated twice a year. The data are stored in spreadsheets, can be obtained via the Web or burned onto CD. Based on discussions with U.S. Regional staff, the price quoted for this package is $6,000. No ongoing subscription fee is required to purchase the data.

Economy.com

Economy.com, Inc. is an independent provider of economic, financial, country, and industry research. Economy.com was founded in 1990, and is based in West Chester, Pennsylvania.

The company's forecasting methodology differs from other vendors in that their model of the U.S. economy incorporates both top-down and bottom-up approaches. In that model, those variables that are national in nature are modeled nationally, while those that are regional in nature are modeled regionally, subject to data availability. In particular, the regional modeling system links each state's economy to other states through migration flows and unemployment rates. Those linkages permit them to take worker mobility into account. The county forecasts are linked into this regional system.

The Economy.com's county forecast "core" database includes approximately 100 variables, including:

- Employment for 9 industry sectors (using NAICS industry designations)
- total and wage & salary income
- population and households
- labor force and unemployment rate
- bankruptcies and retail sales
- residential permit issuance, single-family housing stock, existing sales, sales price, affordability index and mortgage originations

The data series extends to 20 years of forecast at an annual frequency. History and forecasts updated quarterly. The data are available via the Web, and can be downloaded into a variety of common computer programs. The cost for this service for one year is $5,700.

NPA Data Services, Inc.

NPA Data Services, Inc. was established in 1985, and is located in the Washington, DC area. The company specializes in developing county, metropolitan statistical area, state, economic area (EA), region and U.S. databases. The company represents an outgrowth of work done at the National Planning Association.

Regional projections are generated by using linked regional economic and demographic growth models. The regional economic model utilizes the latest detailed data specific to each area to project employment, earnings, personal income, and total population series for the area. The demographic projection model estimates the details of total population by age, sex and race using cohort components analysis, estimates of local fertility and mortality trends, and a set of relationships which characterize the domestic migration patterns of the given area. The sum of the regional economic and demographic projections is constrained by the company's national projections, which act as control total.

The NPA regional databases include historical data and projections for each year from 1967 to 2030 for 56 economic and household data series and 153 population series. The concepts forecasted include:

- Population by age (16 cohorts), race and gender
- Number of households, household size and income per household
- Employment and earnings for 10 sectors (using SIC industry designations)
- Personal Income by component

All databases are updated twice a year. The company distributes this information as hardcopy or on diskettes or CD-ROM. The cost for a single state delivery is $400.

3.7.3. Evaluation and Selection of A Data Vendor

The evaluation of a vendor must be based on a number of selection criteria. First, one must consider the appropriateness of the methodology used in generating the forecast. That is, can the methodology employed to generate county level projections distinguish differential patterns of growth from national and state control totals. It is unlikely, in our opinion, that the Global Insight model could provide this important feature. Instead, we believe that the hybrid models used by Economy.com, NPA or Woods & Poole are more likely to produce distinct, useful county-level forecasts.

Second, it is convenient to utilize a vendor that can provide enough detail to drive the planned county-level models. Simply put, it is much more efficient to obtain all necessary data, both history and forecast, from one source rather than try to construct a coherent database from several different sources.

All of the vendors appear to offer sufficient employment and income data for the purposes of the PENNDOT project. Further, all appear to be able to provide detailed demographic information, which is key to predicting VMT. Some of the vendors also offer other data that may be useful for this project. For example, Woods & Poole provide detailed projections of county level retail sales, which may be helpful in predicting traffic flows. Economy.com provides significant information about residential construction activity at the county level, which may be used to forecast changing traffic patterns over time.

A third important criterion is price. As can be seen from the comparison above there is a wide range of prices offered. Given the differentials, it would appear that Woods & Poole or NPA provide the most economical offerings and they are sufficient to satisfy the needs of the models that will be constructed.

We <u>do not</u> include forecast accuracy as one of our selection criteria for two reasons. First, forecast accuracy can be measured in myriad different ways, depending upon the forecast user's objectives, and can be very sensitive to the time period selected for the test. Our second reason is more fundamental, and less technical in nature. It is our strong belief that the principle value of a long-term forecasting model is that it provides a fixed, coherent structure with which to study infrastructure issues over a long time horizon. All long-term forecasts will miss the mark; a forecasting model that is carefully constructed and used will get the user into the ballpark.

Given our criteria, it is our opinion, at this point, that PENNDOT should select either Woods & Poole or NPA as the data/forecast vendor for this project. Indeed, one idea that we have discussed is that PENNDOT purchase both the Woods & Poole and NPA forecasts, given their relatively low costs. The companies use somewhat different modeling techniques, and so should produce somewhat different forecasts. The two forecasts could then be used as checks on each other, and could be combined into a single, weighted average forecast. There is empirical research that suggests that "averaged" forecasts of this kind are the most accurate. By combining two or more forecasts from different modeling systems, the errors inherent in each particular system tend to cancel one another out and produce the best single forecast.

Subsequently, we evaluated the sample forecasts from both sources. Based on this evaluation and other factors, we recommend that Woods & Poole data be used for this VMT growth forecasting study.

4. Evaluation of Candidate Methods for Detailed Study

In Chapter 3, we reviewed the state of the art and the state of practice in traffic growth forecasting. It was concluded that there was no single, perfect approach for estimating and forecasting traffic growth. However, the review identified approaches and techniques that show the greatest potential for serving the goals and objectives of the Commonwealth.

Table 4-1. Comparing Different Forecasting Methods against PENNDOT Needs

	PENNDOT Needs for a Traffic Growth Forecasting System					
	Forecasting Level of Detail			Forecasting Variables and Data		
Candidate Methods	**Four Area/ Functional Groups[1]**	**County-Level (all counties)**	**Passenger vs. Truck Travel**	**Socioeconomic Variables**	**Traffic Information Variables**	**Land Use**
Methods—Based on the Type of Data Used						
Traffic Count Based Forecasting	X	X	X		X	
Socioeconomic Data Based Methods[2]		X	X	X		
Travel Demand Forecasting Models	X		X	X	X	X
Methods—Based on Forecasting Techniques						
Growth Factors	X	X	X		X	
Time Series Models	X	X	X			
Econometric Modeling (Regressions)	X	X	X	X	X	X

Note:

1. urban interstate, urban non-interstate, rural interstate, and rural non-interstate
2. based on surveys such as NPTS and/or energy consumption such as fuel

Table 4-1 compares what each forecasting method offers with what PENNDOT needs. Some of the forecasting methods reviewed do not serve the PENNDOT needs. For example, socioeconomic-data-based methods such as travel survey-based methods and fuel-consumption-based methods do not produce forecasts by functional class and area groups. They can be used to forecast statewide VMT as a control total for cross-checking. However, both methods have serious limitations. The travel survey data currently used are secondary data sources from national surveys like NPTS. Sampling can introduce a major bias unless a state has an add-on, because these surveys are designed to represent the national population. Fuel-based VMT forecasting has also major limitations in terms of data bias. The estimation and forecasting of fuel economy present the most difficult problem for this method, and fuel consumption across the state borders is another challenging issue for VMT forecasting. Based on the overall evaluation, we do not recommend these two methods in the development of the forecasting system for Pennsylvania. Fuel-based VMT methods may be used for validation purposes.

Travel demand forecasting models from MPOs do not serve all PENNDOT needs because of their limited geographic coverage. However, they can provide useful data for the statewide forecasting system. MPO travel demand models can be used in different ways:

- Use travel demand model output VMT as a cross check
- Use travel demand model input data for socioeconomic forecasting
- Use additional input and output data from travel demand models

MPO model data and results will be examined in Section 6.5 to evaluate candidate statistical models.

The growth factors method is the most popular technique used to do traffic growth forecasting in practice. However, its major limitation is that growth factors do not respond to changing socioeconomic conditions in the future. This method does offer useful information for the forecasting system to be developed in this project. Historical growth factors will be examined, and future growth factors will be estimated from the forecasting system and evaluated against historical trends.

Considering the state of the art and practice in traffic growth forecasting, we recommend testing a range of regression methods (econometric models. Different model specifications should be tested in Ordinary Least Square (OLS) regressions, which are popular in the traffic volume forecasting literature. Additional regression methods may include two-stage least square method, generalized least square method, and non-parametric regression. These methods have been employed in previous research, but have not been used for VMT forecasting purposes. Independent variables will include demographic, economic, and land use variables.

5. Growth Analysis

The objective of this analysis was to review current and historical traffic and socioeconomic growth patterns within the Commonwealth and identify future socioeconomic growth trends. Historical traffic and socioeconomic growth patterns are crucial to understand the underlying causes of traffic growth and the relationships between traffic growth and socioeconomic variables. Socioeconomic growth trends will play a critical role in shaping traffic growth in the future. This descriptive analysis will lay a solid foundation for developing quantitative, statistical models in the next section. Description of the data used in this growth analysis and modeling can be found in Section 6.1.

To achieve this objective, historical traffic growth patterns were analyzed by stratifying the data into several different subcategories, including: county, county groups, functional class, functional class groups, county/functional class groups. We concentrated on four stratifications based on functional classes and area types—urban interstate, urban non-interstate, rural interstate, and rural non-interstate. Total VMT growth is the focus of this analysis, but we also touch on truck traffic growth patterns. Our geographic units of analysis are county and county groups.

Similarly, historical socioeconomic growth patterns by county and county groups were analyzed. Major socioeconomic variables include

- Number of households
- Population/population density
- Employment/employment density
- Per capita income/Household income
- Population by Age, and
- Retail Sales

The socioeconomic forecast data recommended in Chapter 3 were used to analyze future socioeconomic growth patterns by county and county groups. GIS is used for display and descriptive analyses. Historical and future growth patterns were compared, with particular attention to how growth patterns differ between the past and the future.

5.1 Traffic Growth Analysis

As shown in Table 5-1, long-term growth trends between 1980 and 2003 include:

- Statewide total VMT grew by almost 50 percent, representing a compound annual growth rate of 1.7 percent.
- Pennsylvania's historical VMT growth is lower than the national average, which has averaged over 3 percent since 1970.
- Overall VMT growth appears to be moderating; 1.8 percent for the 1980-1989 period versus 1.5 percent for the 1994-2003 period.

- Interstate VMT increased at a higher rate (3.9 percent annually) than non-interstate VMT (1.2 percent annually).
- Urban interstate VMT grew more rapidly than rural interstate VMT, with annual growth rates of 5.2 and 2.6 percent, respectively.
- Urban interstate VMT growth appeared to be moderating, but rural interstate VMT grew at a faster pace over the recent past decade than in the 1980s.

Table 5-1. Long Term Historical VMT Annual Growth Rates

	RURAL INTERSTATE	URBAN INTERSTATE	RURAL NON-INTERSTATE	URBAN NON-INTERSTATE	TOTAL STATEWIDE	TOTAL US
1980-1989	2.60%	5.70%			1.80%	3.60%
1994-2003	4.10%	4.80%	-0.80%	1.90%	1.50%	2.40%
Total (1980-2003)	2.60%	5.20%			1.70%	2.80%

As shown in Tables 5-2 and 5-3, short-term growth trends between 1994 and 2003 include:

- Statewide VMT increased at a lower rate in 2000 and after, with a rate of 1 percent compared with 2 percent for the years before 2000.
- Interstate VMT grew more rapidly than non-interstate VMT, averaging 4.8 and 0.8 percent annually for interstates and non-interstates, respectively.
- Reclassification in 2003 significantly affects lane miles and VMT distribution among the four categories—a significant shift from rural to urban categories (Figures 5-1, 5-2 and 5-5).
- VMT growth rates, for most years, move in tandem with lane mile growth rates; this is particularly evident for the 2003/2002 and 1996/1995 growth rates (Figure 5-3 and5-4).
- Truck VMT growth shows similar patterns as total VMT (see Table 5-3).

Table 5-2. Short Term Statewide Total VMT Annual Growth Rates

	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03
Rural Interstate	5.3	20.3	3.3	4.6	4.2	1.2	1.3	5.4	-6.9
Rural Non-Interstate	2.1	-0.9	2.8	1.9	3.7	0.0	0.1	0.1	-16.0
Urban Interstate	6.1	2.7	3.8	4.3	2.9	1.0	3.9	2.7	9.8
Urban Non-Interstate	0.6	0.3	0.4	0.6	-0.1	-0.9	0.8	0.1	14.7
Total	2.4	2.0	2.0	2.1	2.1	-0.1	1.1	1.1	1.2

Table 5-3. Short Term Statewide Truck VMT Annual Growth Rates

	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03
Rural Interstate	6.6	11.8	6.1	4.4	3.7	3.1	1.4	3.5	-5.0
Rural Non-Interstate	2.3	1.1	3.0	2.2	1.9	0.3	-0.6	-0.7	-18.2
Urban Interstate	3.5	0.7	2.9	5.8	2.7	1.6	6.1	3.2	11.6
Urban Non-Interstate	0.1	0.0	0.4	0.2	-0.3	-1.1	0.8	-0.8	29.7
Total	3.1	3.5	3.3	3.1	2.1	1.1	1.6	1.3	0.8

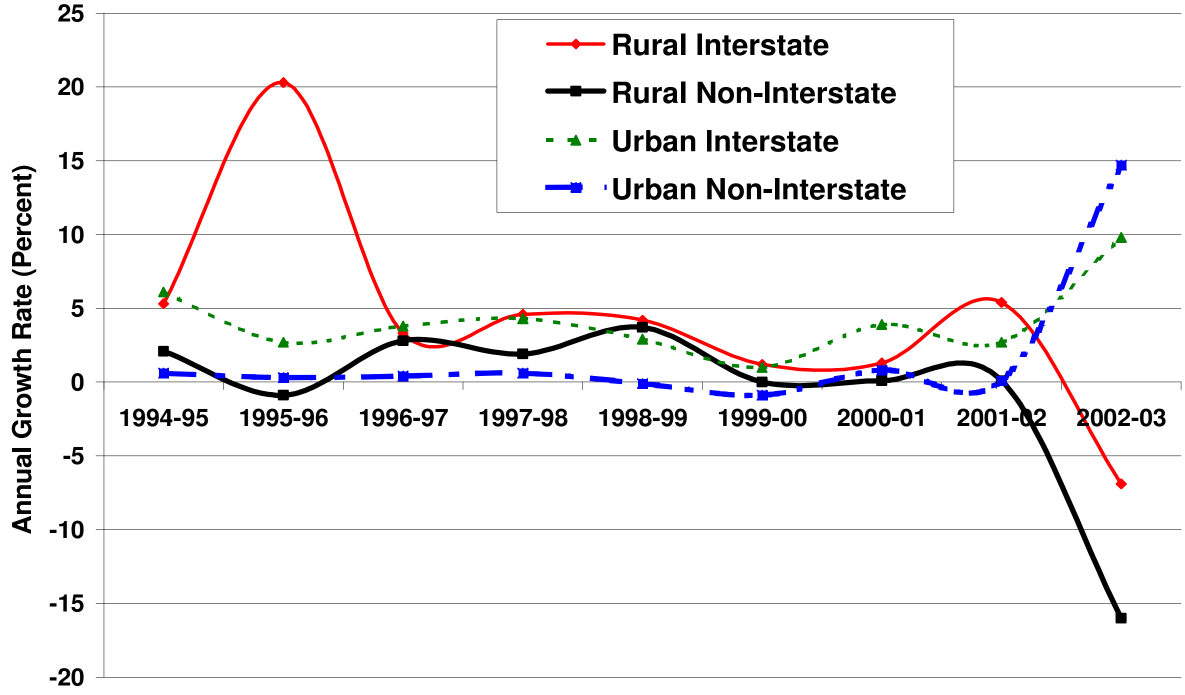


Figure 5-1. Statewide VMT Growth Rates between 1994 and 2003

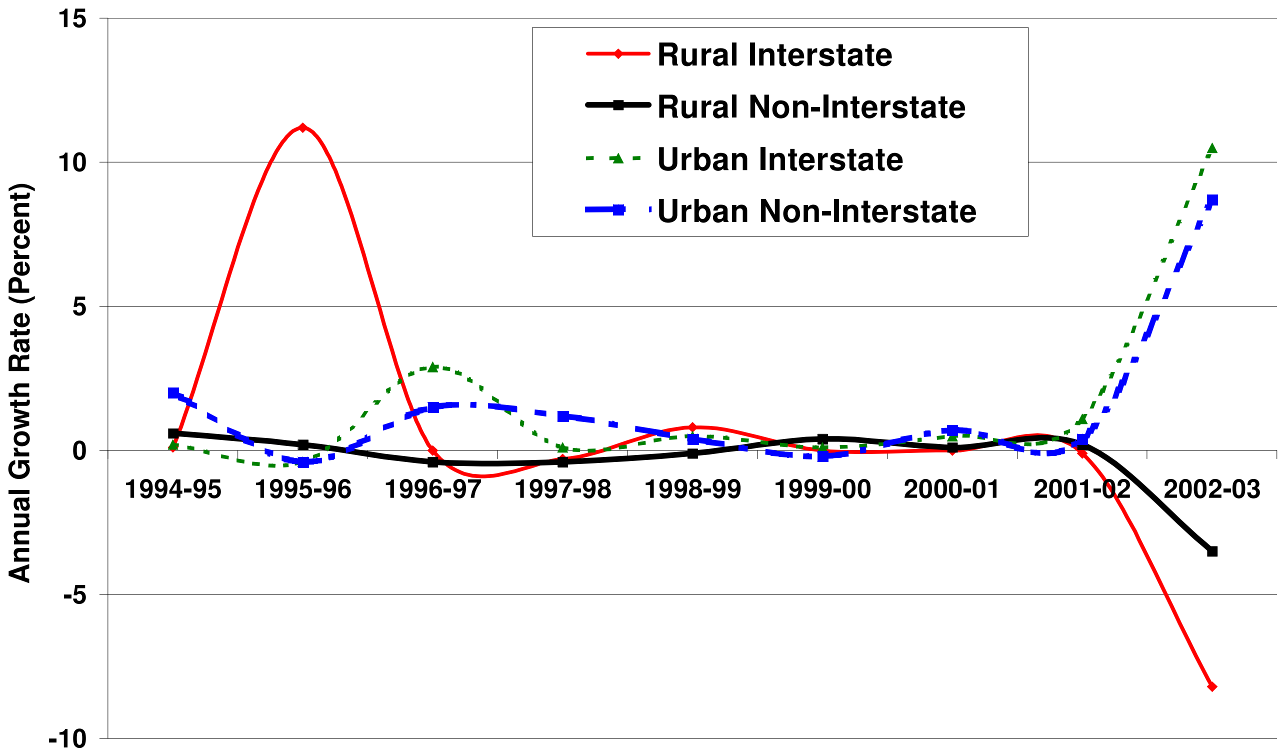


Figure 5-2. Statewide Lane Mile Growth Rates between 1994 and 2003

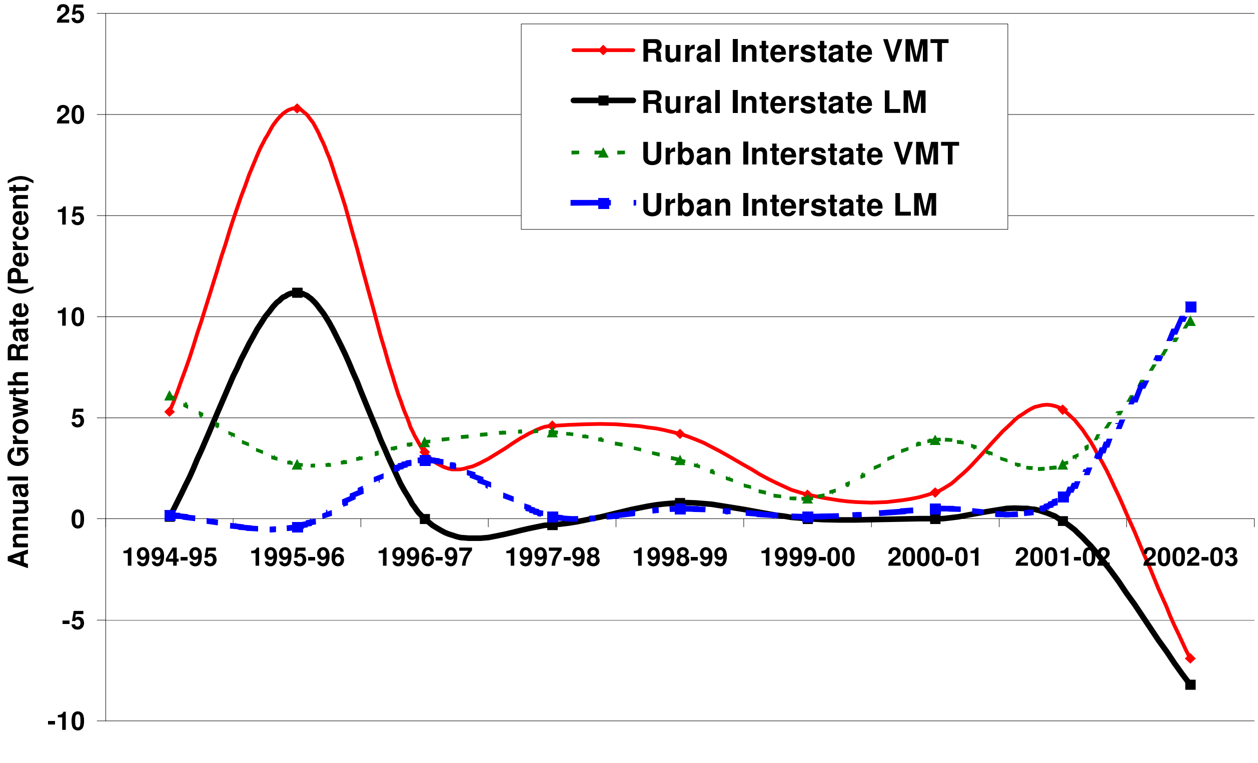


Figure 5-3. Statewide Interstate VMT and Lane Mile Growth Rates between 1994 and 2003

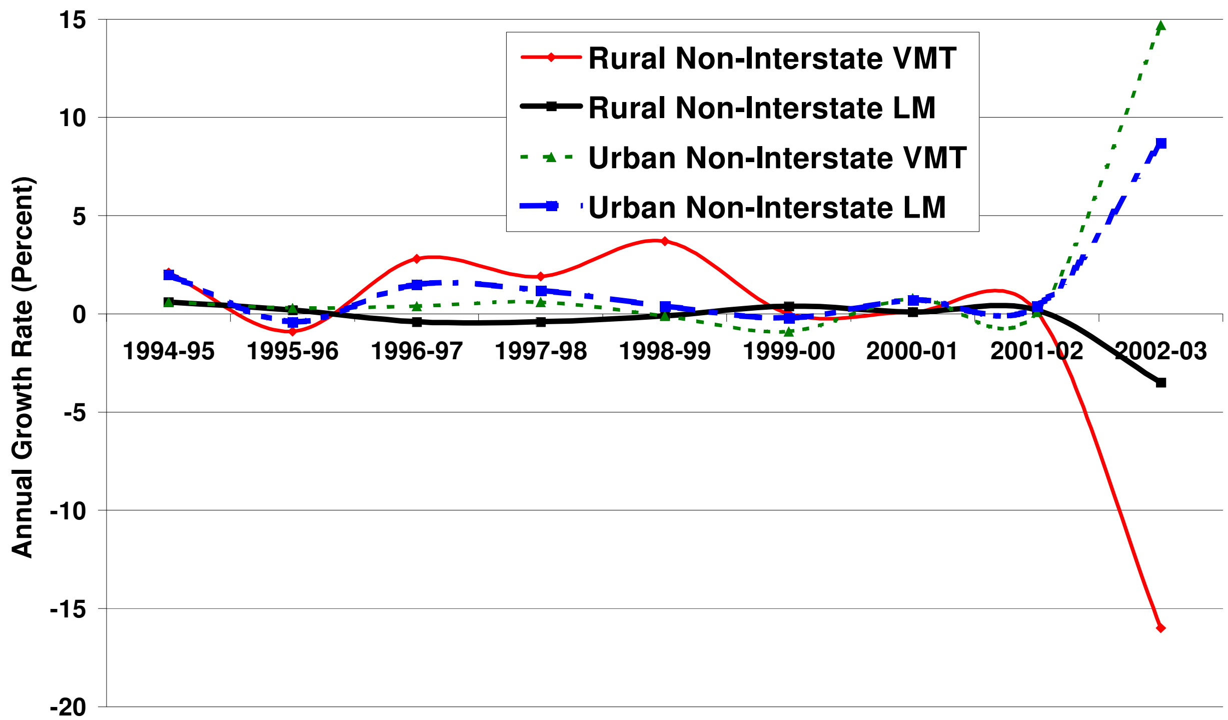


Figure 5-4. Statewide Non-Interstate VMT and Lane Mile Growth Rates between 1994 and 2003

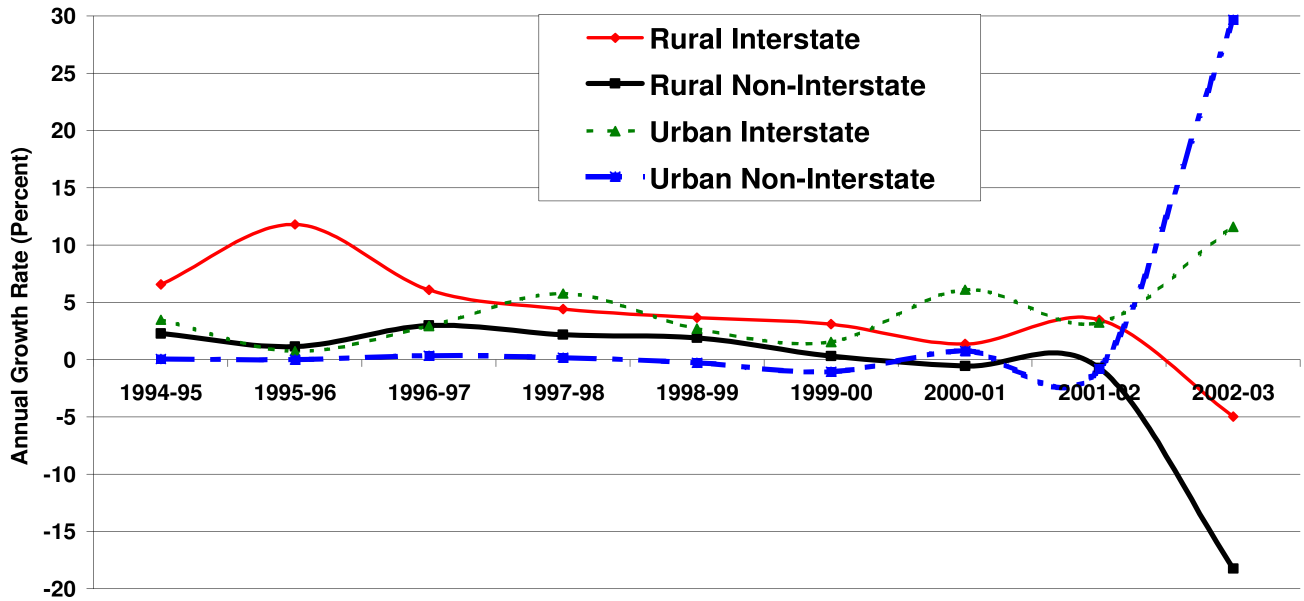


Figure 5-5. Statewide Truck VMT Growth Rates between 1994 and 2003

5.2 Socioeconomic Growth Analysis

As shown in Table 5-4 and Figures 5-6 through 5-29, long-term growth trends between 1970 and 2000 include:

- Statewide population growth has been slow in the last three decades, with less than a 0.5 percent annual growth rate.
- Households grew at a faster rate than population.
- Employment increased at a rate of around 1 percent.
- Income growth rates were higher than population, households and employment (Figure 5-8)
- The state has been losing the young population and gaining the elderly population (Figures 5-6 ,5-12 and 5-13).
- The state has been aging, despite the elderly population increasing at a much lower rate in the 1990s than in the previous two decades.
- Significant regional differences are shown in geographic patterns of growth— strong growth in the eastern and south-central regions and decline and stagnancy in the western and northern regions (Figures 5-16, 5-17, 5-19, 5-20, 5-22, 5-23, 5-25, 5-26, 5-28 and 5-29).
- Older urban areas have declined in population, while population has spread out to urban fringes and exurban areas (Figures 5-16 and 5-17).

Table 5-4 and Figures 5-9, 5-10 and 5-11, show the following forecasted trends between 2000 and 2030:

- Population growth rates will increase, catch up and even surpass the declining household growth rates in the next twenty years.
- Employment will grow at a slightly lower rate than the past three decades.
- Income growth will be moderating but still much higher than population and household growth.
- The state will continue to age, more rapidly after 2010 as baby-boomers enter the senior ranks.
- Regional divide and urban sprawl are forecast to continue in the next 25 years unless strong government policies reverse the trends (Figures 5-18, 5-21, 5-24, 5-27, and 5-30).

Table 5-4. Long Term Annual Growth Rates

	1970-80	1980-90	1990-00	2000-10	2010-20	2020-30
Population	0.05%	0.03%	0.32%	0.27%	0.36%	0.45%
Households	1.25%	0.63%	0.60%	0.53%	0.42%	0.23%
Employment	0.76%	1.19%	0.98%	0.75%	0.89%	0.97%
Income PerCapita	2.50%	1.92%	1.73%	1.20%	1.25%	1.27%
Mean HH Income	1.34%	1.24%	1.30%	0.90%	1.16%	1.41%
Pop <17 yrs	-2.16%	-1.08%	0.04%	-0.79%	0.09%	0.09%
Pop 65+ yrs	1.87%	1.71%	0.13%	-0.26%	1.82%	1.87%
Retail Sales	1.34%	1.46%	2.63%	1.38%	1.38%	1.50%

As shown in Table 5-5, short-term growth trends between 1994 and 2003 include:

- Population growth was low, while household growth was higher than population growth.
- Employment and income growth peaked in the late 1990s and has become weaker since 2000.
- The state lost young population, while the elderly's share of total population remained stagnant or declined slightly during the period.

Table 5-5. Short Term Annual Growth Rates

	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03
Population	0.27%	0.18%	0.06%	0.15%	0.15%	0.18%	0.14%	0.26%	0.33%
Households	0.87%	0.98%	0.37%	0.35%	0.26%	0.64%	0.37%	0.53%	0.64%
Employment	1.61%	0.90%	1.74%	1.39%	1.51%	2.09%	0.16%	0.80%	0.83%
Income PerCapita	0.65%	2.10%	2.60%	3.74%	1.53%	3.67%	0.84%	1.36%	1.19%
Mean HH Income	0.00%	1.09%	2.10%	3.35%	1.20%	3.14%	0.53%	1.04%	0.82%
Pop <17 yrs	0.00%	-0.41%	0.00%	-0.42%	-0.42%	-0.84%	-0.85%	-0.85%	-0.43%
Pop 65+ yrs	0.64%	0.00%	0.00%	0.00%	-0.63%	-0.64%	0.00%	-0.64%	-0.65%
Retail Sales	1.81%	3.02%	1.33%	2.97%	6.22%	4.63%	-0.14%	3.68%	1.31%

Figure 5-6. Social Data Growth Trends 1970-2000

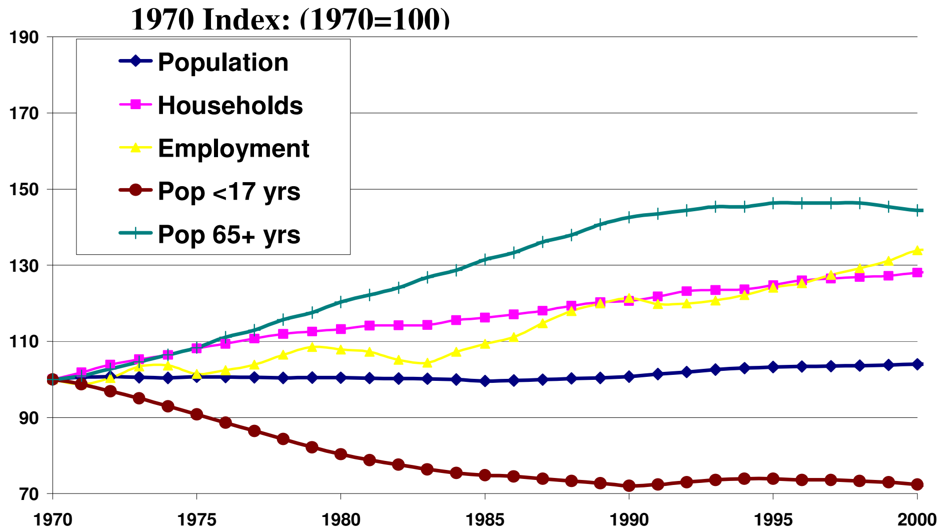


Figure 5-7. Economic Growth Trends 1970-2000

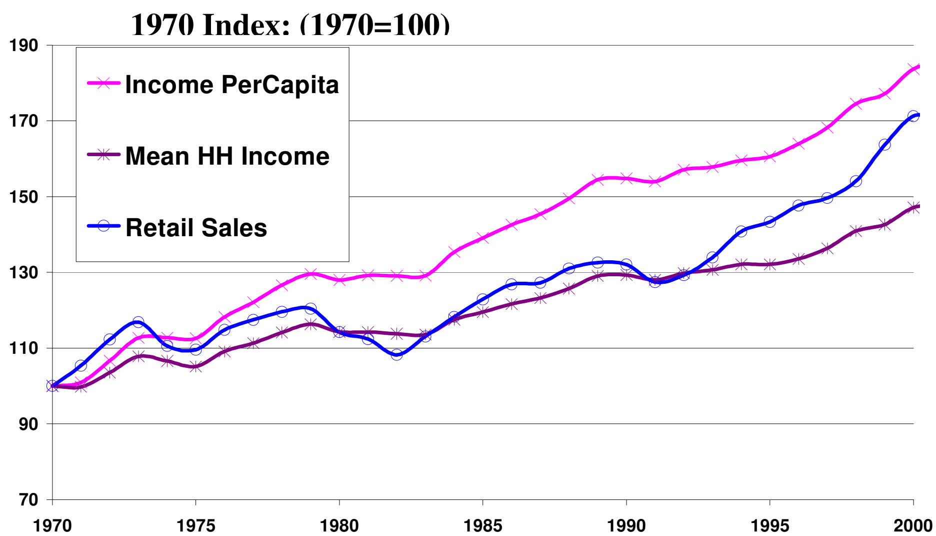


Figure 5-8. All Data Growth Trends 1970-2000

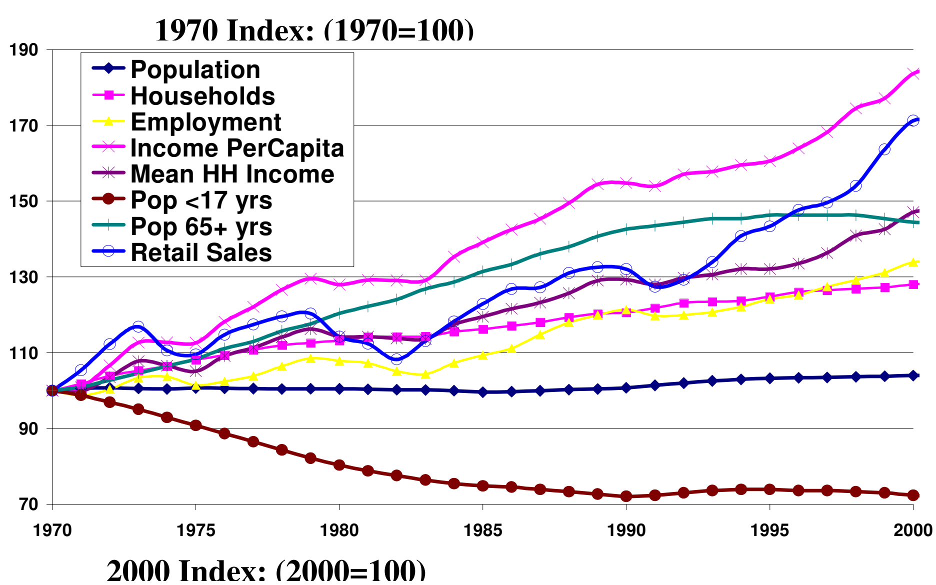


Figure 5-9.
Social Data
Growth Trend
Forecasting
2000-2030

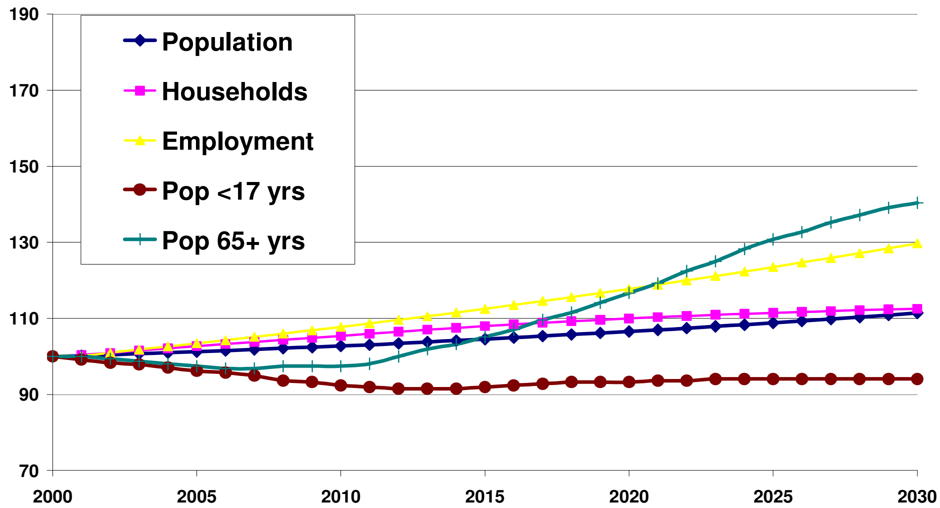


Figure 5-10.
Economic Data
Growth Trend
Forecasting
2000-2030

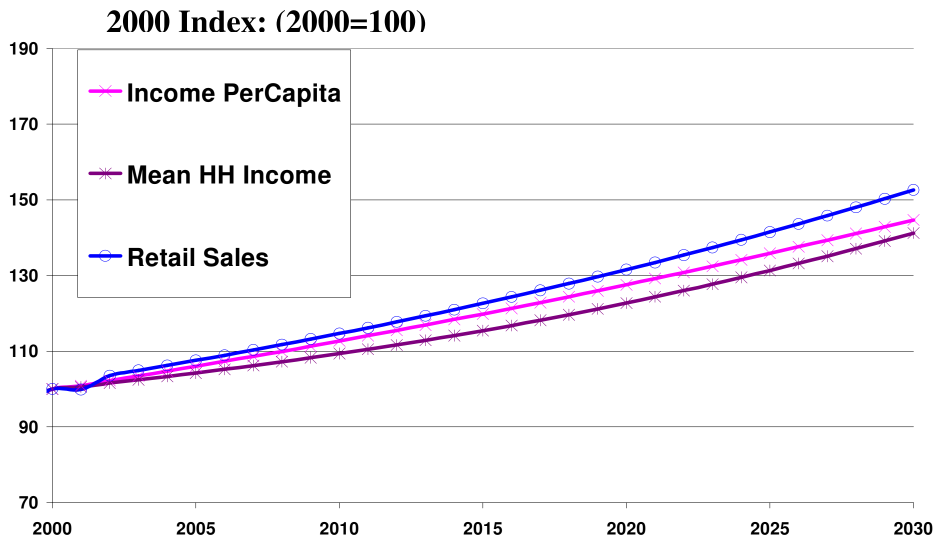
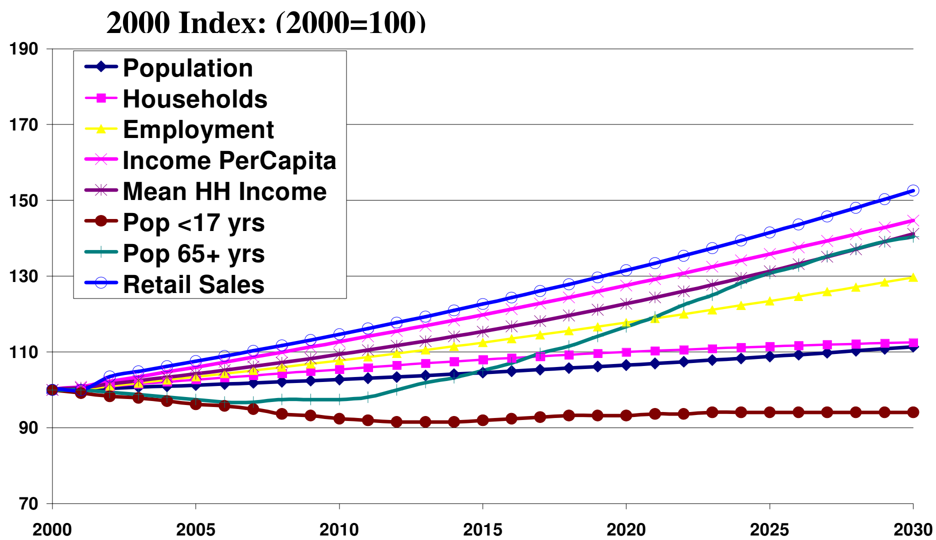


Figure 5-11.
All Data
Growth Trend
Forecasting
2000-2030



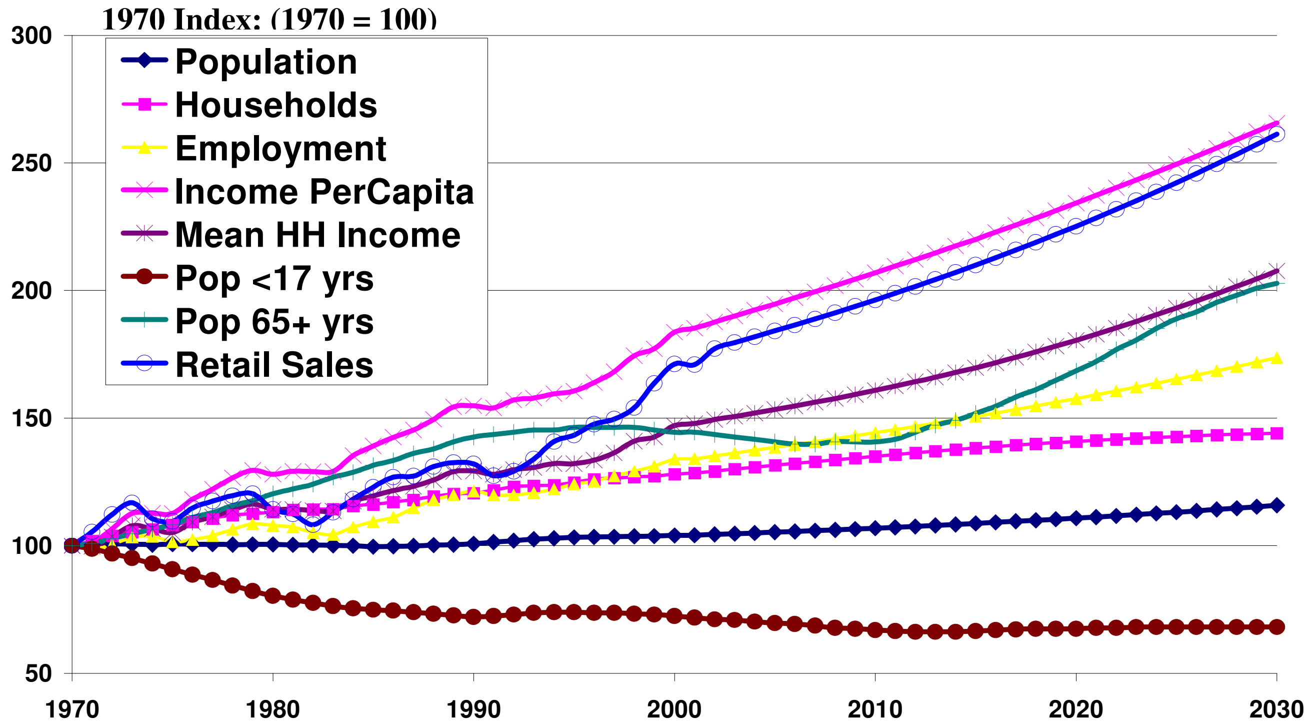


Figure 5-12. Socioeconomic variables trends between 1970 and 2030

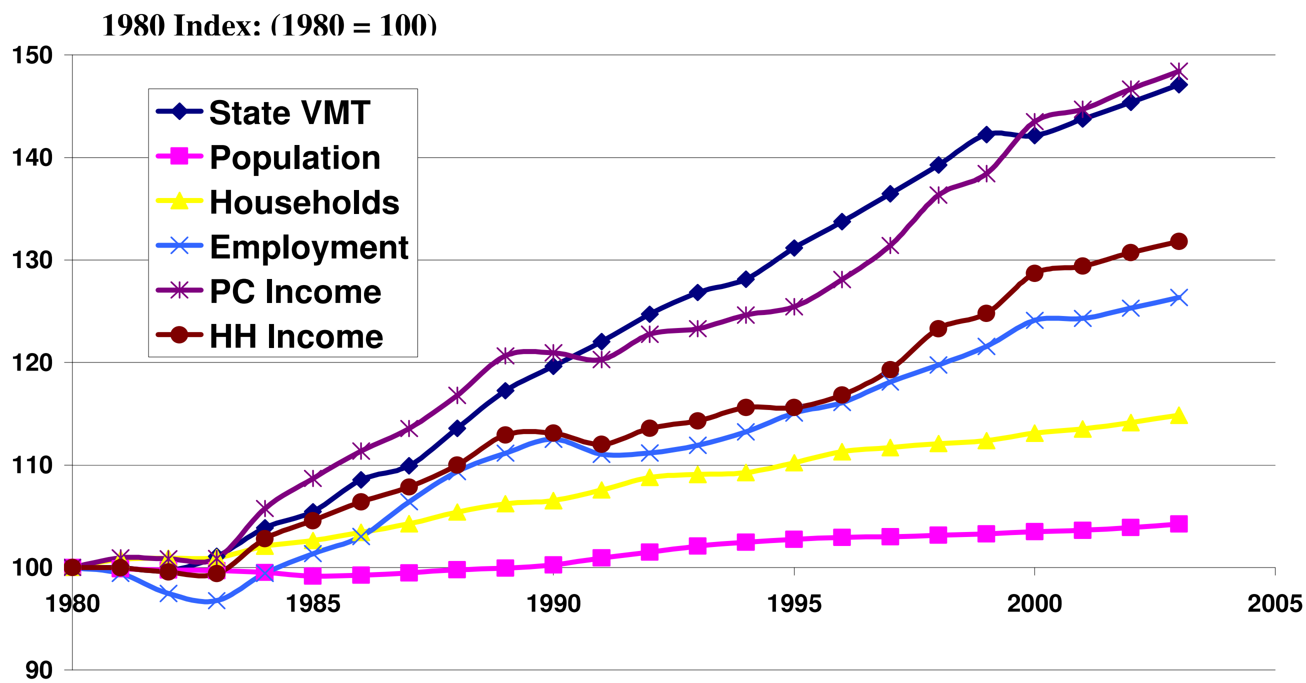


Figure 5-13. Comparison of VMT trend with Socioeconomic Variables between 1980 and 2003

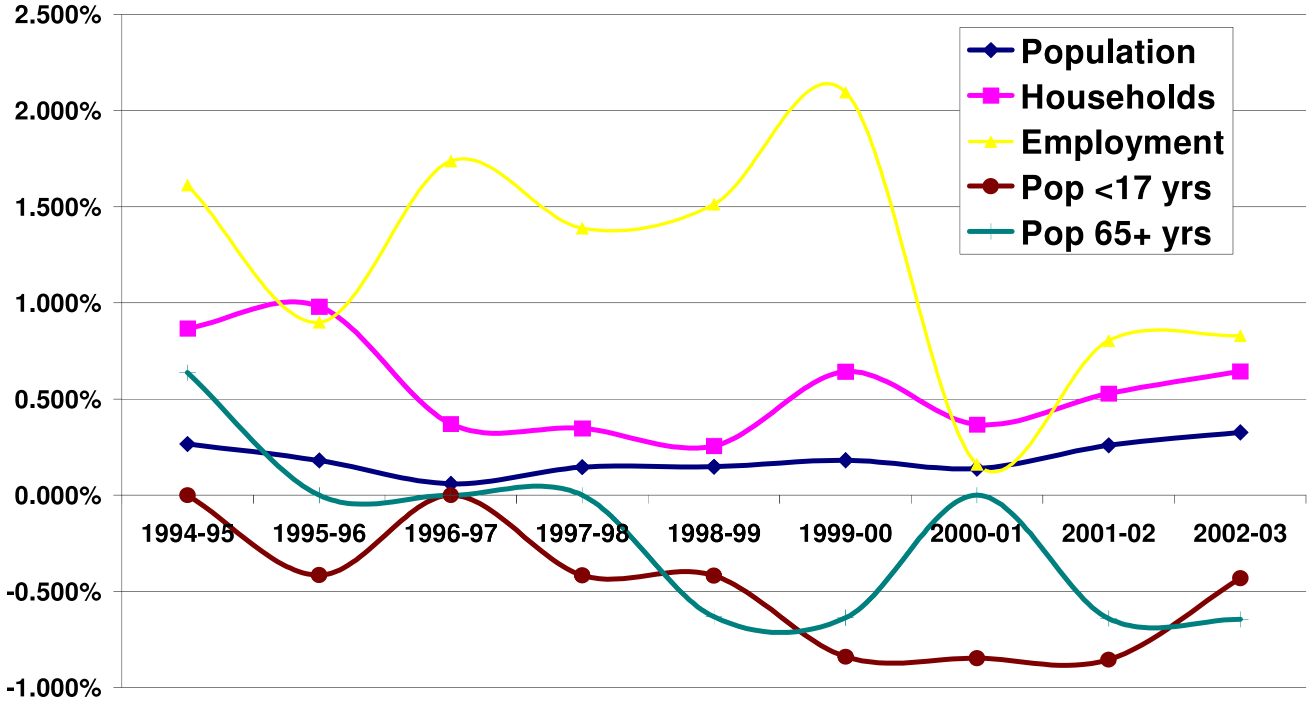


Figure 5-14. Social variables growth rates between 1994 and 2003

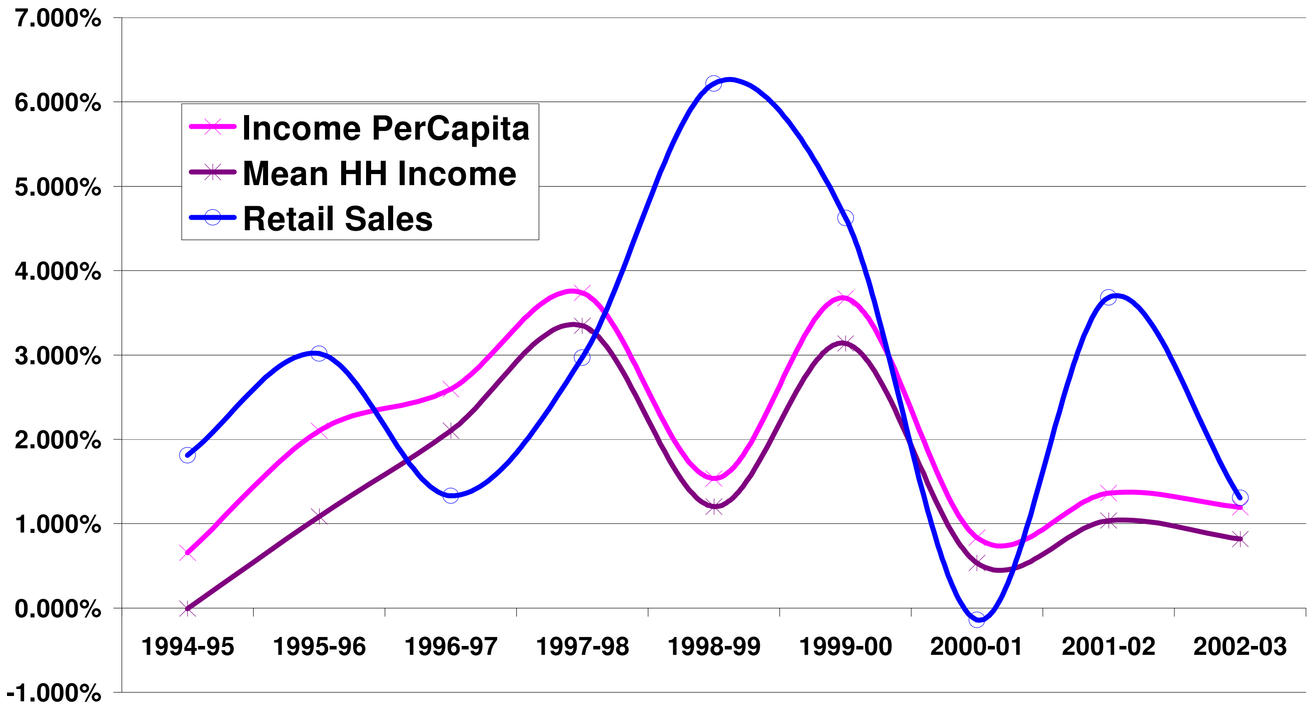


Figure 5-15. Economic variables growth rates between 1994 and 2003

Figure 5-16. Population Annual Growth Rates 1970-1990

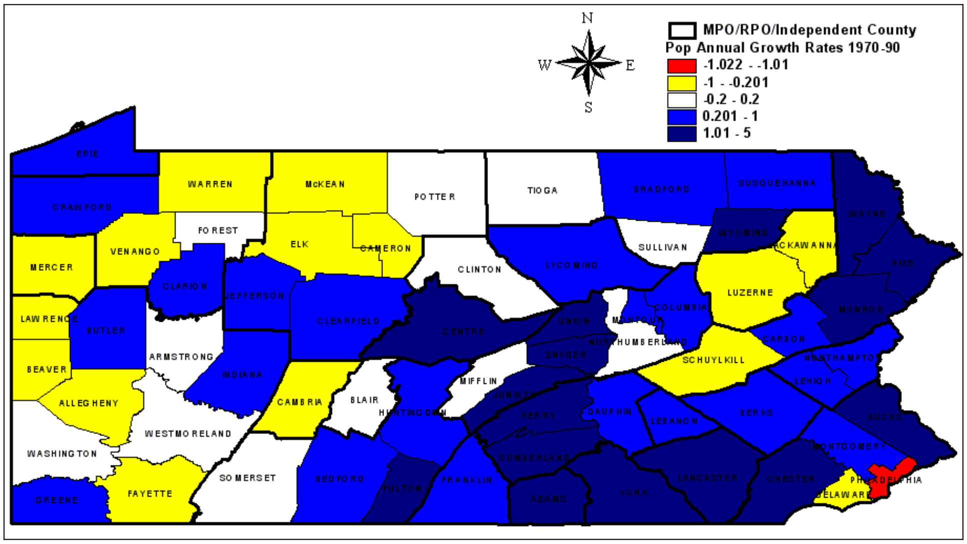


Figure 5-17. Population Annual Growth Rates 1990-2000

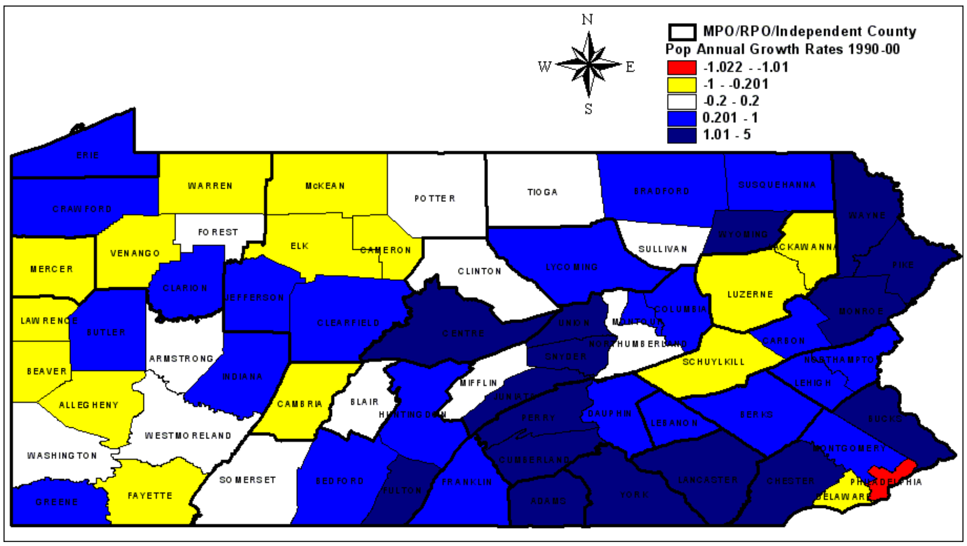


Figure 5-18. Population Annual Growth Rates 2000-2030

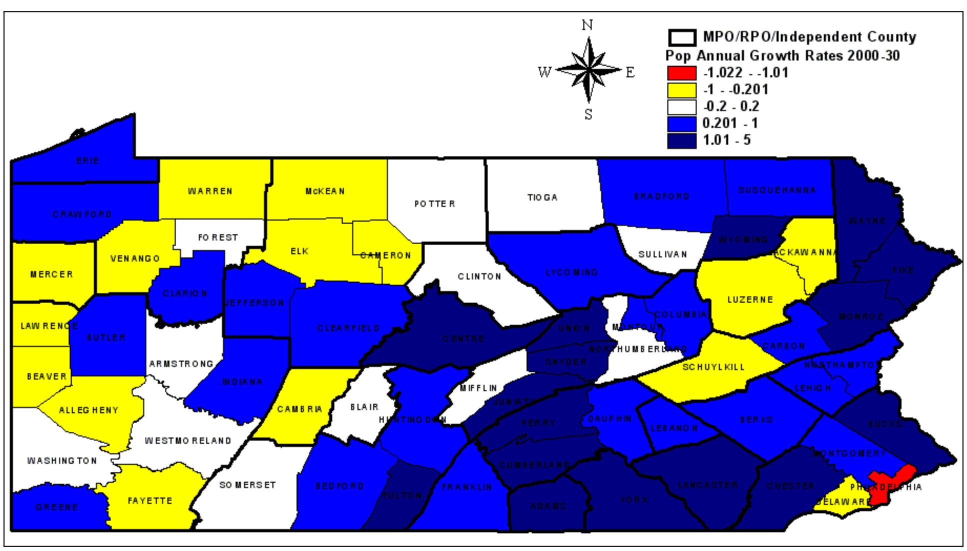


Figure 5-19. Households Annual Growth Rates 1970-1990

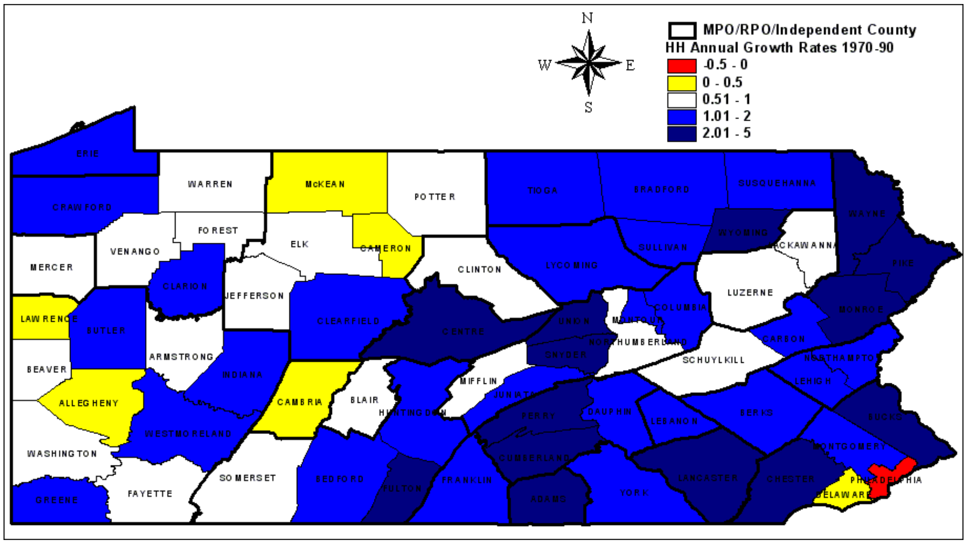


Figure 5-20. Households Annual Growth Rates 1990-2000

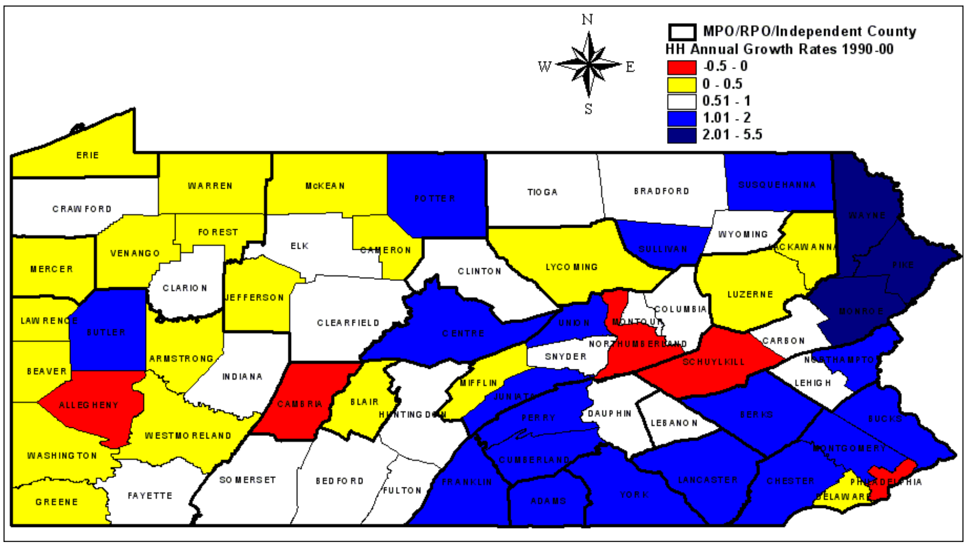


Figure 5-21. Households Annual Growth Rates 2000-2030

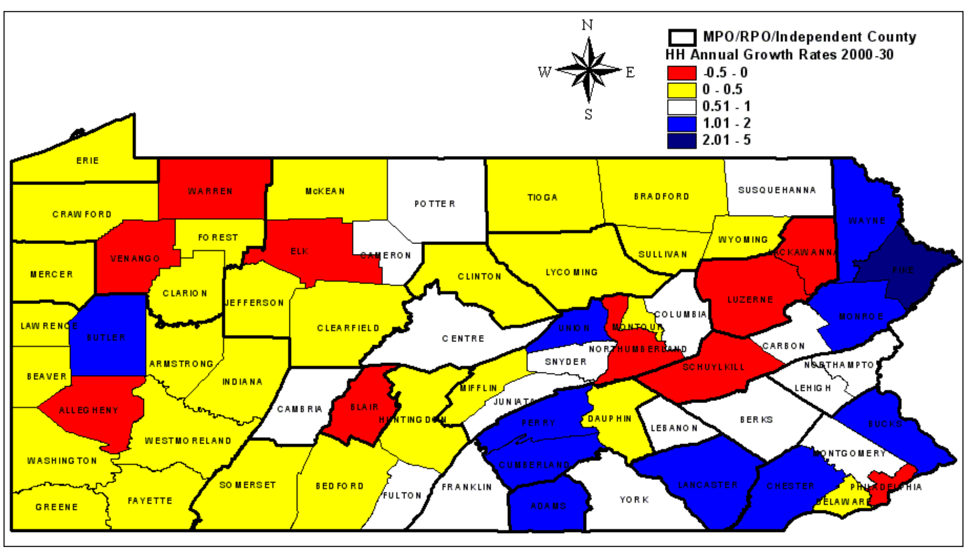


Figure 5-22. Employment Annual Growth Rates 1970-1990

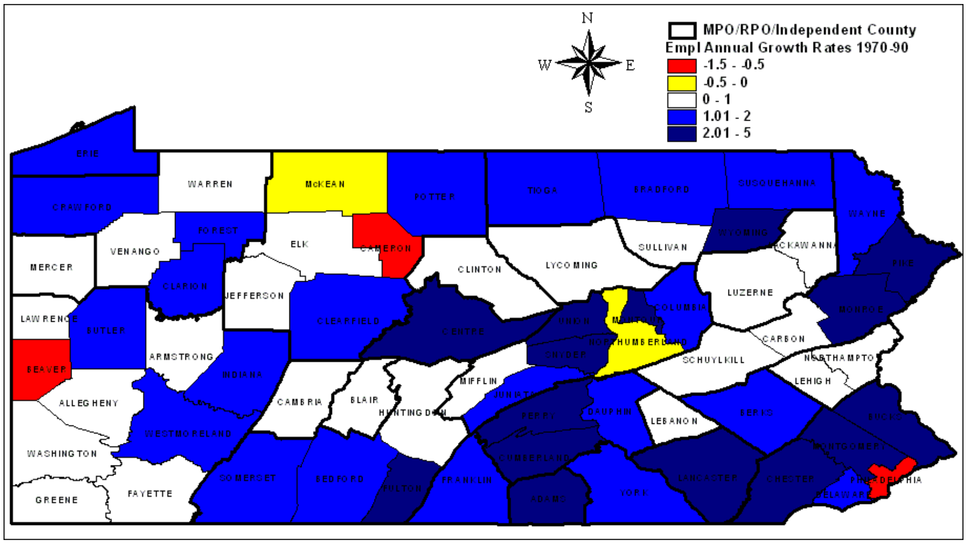


Figure 5-23. Employment Annual Growth Rates 1990-2000

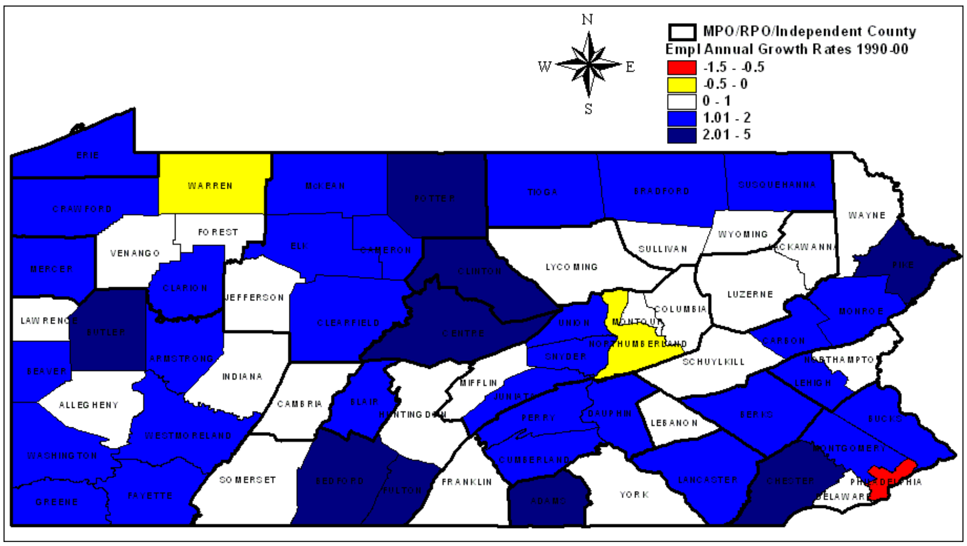


Figure 5-24. Employment Annual Growth Rates 2000-2030

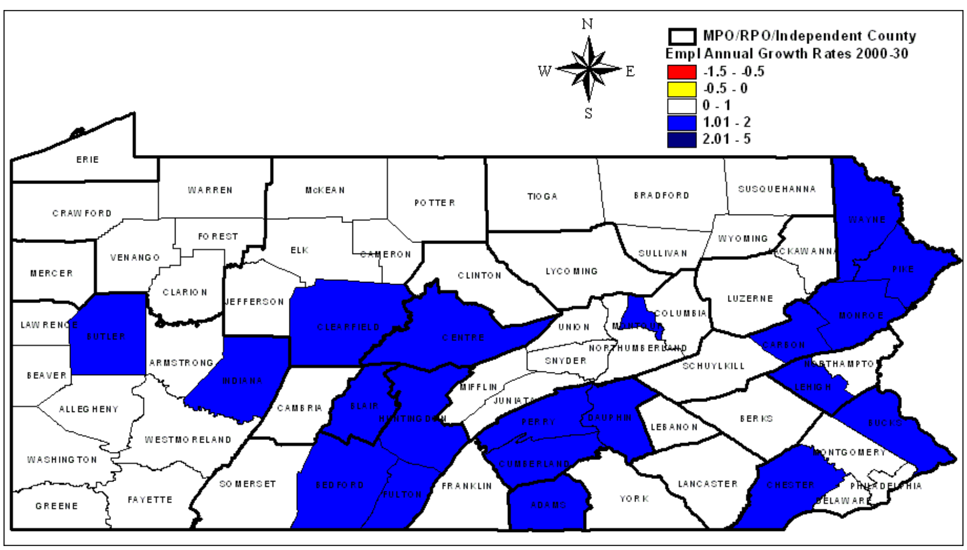


Figure 5-25.
Per Capita
Income
Annual Growth
Rates 1970-1990

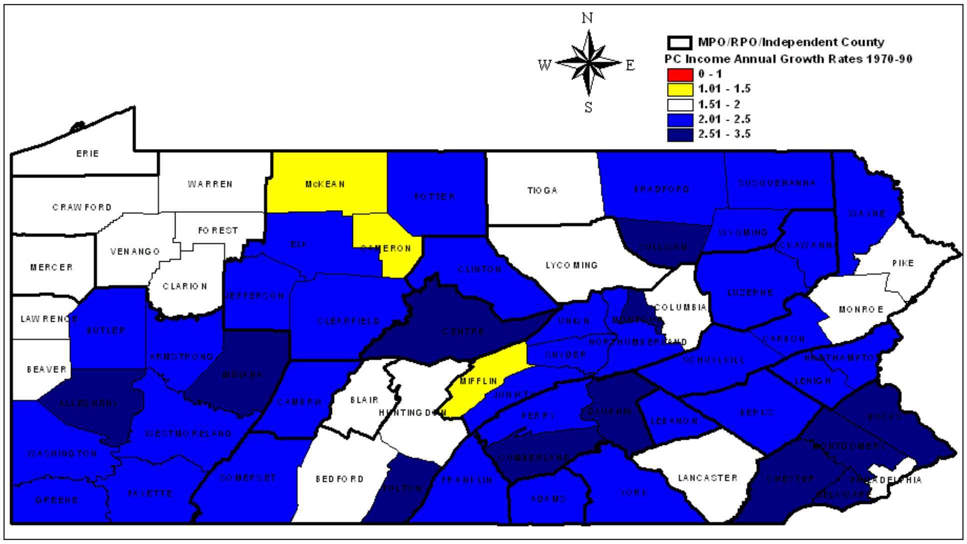


Figure 5-26.
Per Capita
Income
Annual Growth
Rates 1990-2000

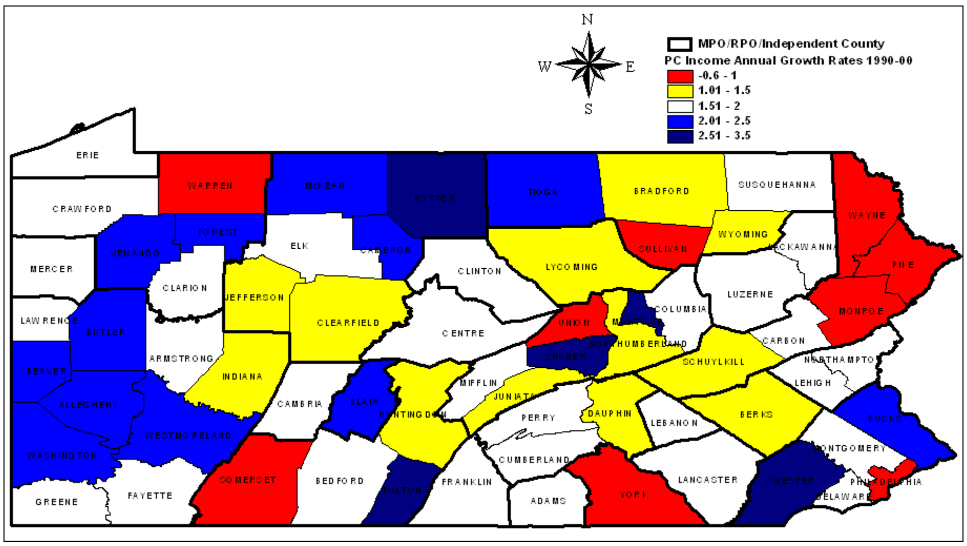
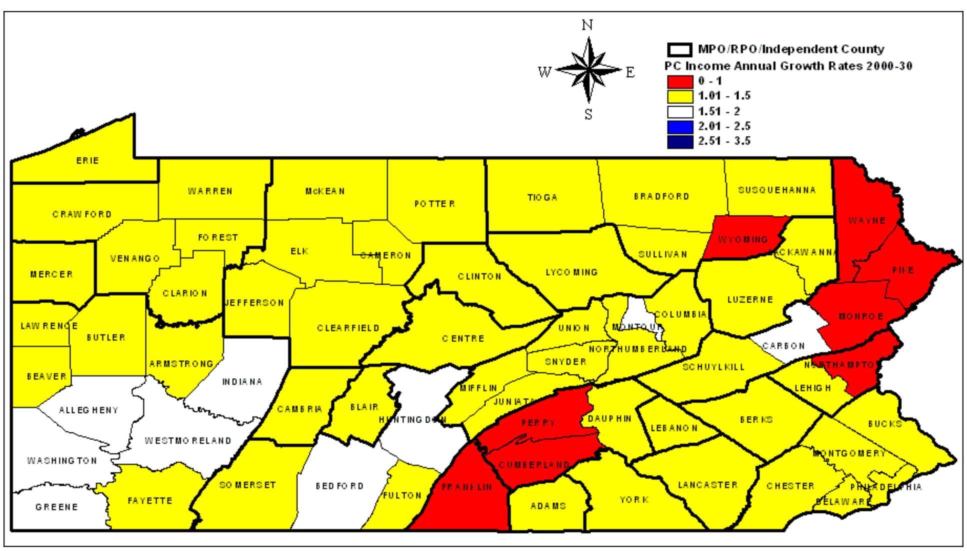


Figure 5-27.
Per Capita
Income
Annual Growth
Rates 2000-2030



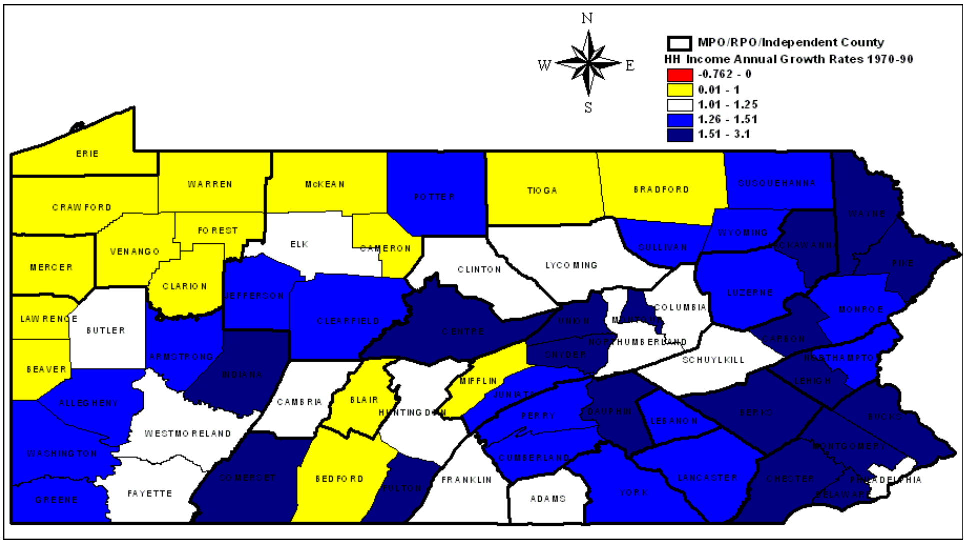


Figure 5-28. Household Income Annual Growth Rates 1970-1990

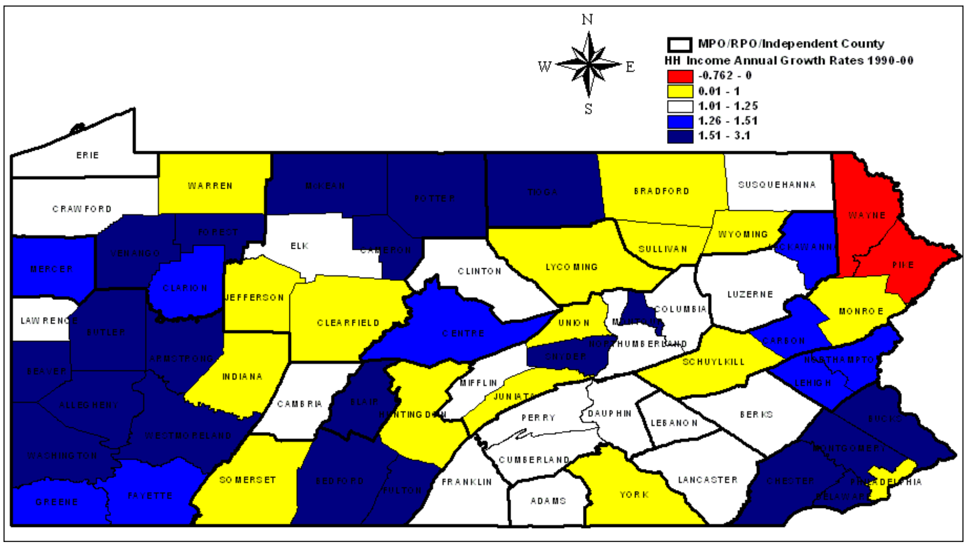


Figure 5-29. Household Income Annual Growth Rates 1990-2000

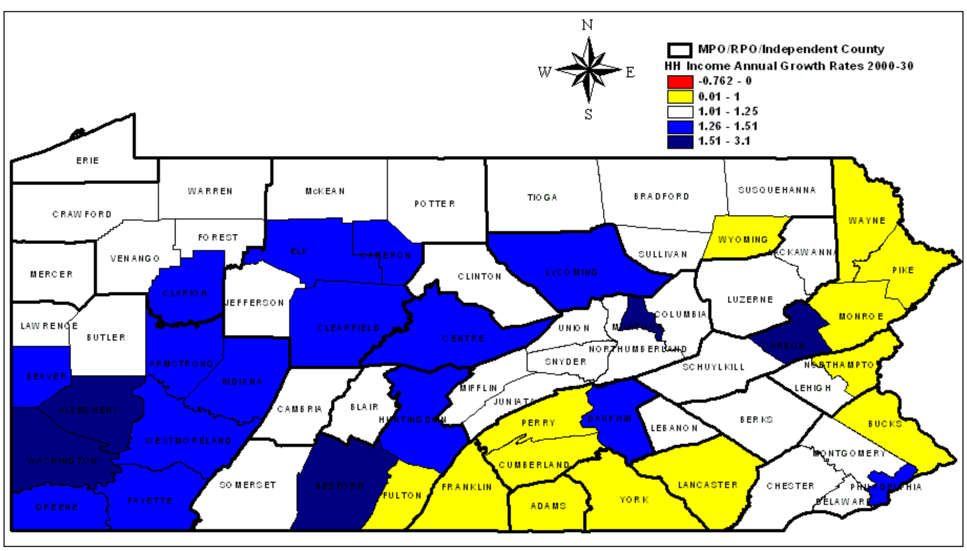


Figure 5-30. Household Income Annual Growth Rates 2000-2030

6. Statistical Modeling of Traffic Growth

The objective of this modeling effort is to develop several statistical models based on historical traffic and socioeconomic data to forecast traffic growth in the Commonwealth and to evaluate the predictive power and reliability of the best statistical models.

6.1. Data and Variables

A number of data sources were used to develop the models in this study. The Bureau of Planning and Research at the PENNDOT provided an extensive traffic database. This database includes the VMT, linear mile, and lane mile by FHWA functional classification, by county, by year, for all public roads for the years between 1994 and 2003. These data are also available for roadways with federal aid only, for the years between 1994 and 2003. Truck VMT data are also available, but only for PENNDOT maintained roads for the years between 1993 and 2003, while no corresponding lane miles were provided.

The 2004 State Profile, developed by Woods & Poole Economics, is the major source for socioeconomic data in this study. In Task1, Econsult, a subcontractor to Baker, reviewed socioeconomic data and forecasting methods and recommended two data vendors—Woods & Poole Economics and NPA data services. Data samples were requested from both vendors and after an extensive evaluation, Woods & Poole data were chosen for implementation in this project. The 2004 State Profile includes historical data and forecasts by year from 1969 through 2030 for every county and MSA in Pennsylvania. The State and U.S. totals are also included. Both historical and forecast data have annual frequency. Variables in the 2004 State Profile database include:

- Population by age (single year cohorts), gender and race
- Number of households, household size and households by income level for 11 income ranges
- Employment and earnings for 13 sectors (using SIC industry designations)
- Personal Income by component
- Retail Sales for 10 sectors
- Educational Attainment (history only)
- Labor force and unemployment (history only)
- Private Non-farm Establishments by size and industry (history only)

As can be seen in Table 6-1, a variety of variables, different forms of these variables, and indices have been tested in the statistical modeling process. These include the natural logarithmic forms and the difference (growth) forms of these variables, as well as density and mix indices. These variables were used at the county and county grouping levels. The grouping of counties is based on a few factors, including census defined metropolitan areas, metropolitan planning organization areas, rural planning organization areas, CTPP worker flow data, and major interstate corridors. The idea is to identify groups of counties that have strong social and economic interrelationships, which have significant effects on the group's highway travel but no significant effects outside the group. As a result, thirteen groups of counties were identified (see Table 6-2 and Figure 6-1).

Table 6-1. Variables Tested in the Regression Modeling

Dependent Variables		VMT	VMT
		LN_VMT	Ln(VMT)
		Diff_VMT	$VMT_{94\text{-}95} = VMT_n - VMT_{n-1}$ (e.g. $VMT_{1995} - VMT_{1994}$)
		LNVMTPC	Ln(VMT / County Population)
		logdiff_VMT	$Ln(VMT_n) - LN(VMT_{n-1})$
		logdiff_LM	$Ln(LM_n) - LN(LM_{n-1})$
Independent Variables		YEAR	Year
	BASE VARIABLES	EMPL	County Employment
		HH	County Households
		INCHH	County Mean HH Income
		INCPC	County Income per Capita
		POP	County Population
		LM	County Lanes Miles by Category
		POPDEN	Population Density (County Population / County Area)
		EMPDEN	Employment Density (County Employment / County Area)
		COMDEN	Combined Density $POP + (\frac{StatePopulation}{StateEmployment})EMP \Big/ AREA$
		LUMIX	Land Use Mix Index $[HH * (\frac{StateEmployment}{StateHH})] * EMP \Big/ [HH * (\frac{StateEmployment}{StateHH})] + EMP$
		LN_(Base Variables)	Natural Logarithm of Base Variables e.g. LN_HH = LN(HH)
		LNLM*PC	LN (Lane Miles for each functional Class / County Population)
		LNVMT*PC	LN (VMT for each functional Class / County Population)
		Diff_(Base Variables)	Difference of each variables between two consecutive years e.g. $EMPL_{94\text{-}95} = EMPL_n - EMPL_{n-1}$ (e.g. $EMPL_{1995} - EMPL_{1994}$)
		logdiffPop	$Ln(POP_n) - LN(POP_{n-1})$
		logdiffPCI	$Ln(INCPC_n) - Ln(INCPC_{n-1})$
		logdiffHH	$Ln(HH_n) - Ln(HH_{n-1})$
		logdiffHHI	$Ln(INCHH_n) - Ln(INCHH_{n-1})$
		logdiffLM	$Ln(LM_n) - Ln(LM_{n-1})$
		logdiffLM2	$Ln(LM_n) - Ln(LM_{n-2})$
		Dummy Variable	0 or 1 for each Year & 0 or 1 for each County or County Group
		INC_Low	Percent households in the lowest quartile of household income distribution
		INC_VHigh	Percent households in the highest quartile of household income distribution
		Pop17	Percent population aged under 17 years old
		Pop65+	Percent population aged over 65 years old
		RETS	County Retail Sales (in 1996 dollars)
		LN_RETS	Ln(RETS)

Table 6-2. County Group Definition

IDENTIFIER	County Group Name	Counties
ALTGR	Altoona Group	Bedford, Blair, Cambria, Fulton, Huntingdon, Somerset
CNTRGR	Centre Group	Centre, Clearfield, Clinton, Lycoming
EPAGR	East PA Group	Berks, Carbon, Lehigh, Northampton
HARRGR	Harrisonburg Group	Adams, Cumberland, Dauphin, Franklin, Lancaster, Lebanon, Perry, York
I81GR	I-81 Group	Lackawanna, Luzerne, Schuylkill, Susquehanna, Wyoming
NCNTGR	North Centre Group	Cameron, Elk, Forest, McKean, Potter, Warren
NEPAGR	NE PA Group	Monroe, Pike, Wayne
NTIERGR	Northern Tier Group	Bradford, Sullivan, Tioga
PHILY	Philadelphia Group	Bucks, Chester, Delaware, Montgomery, Philadelphia
SEGA-COG	SEGA-COG	Columbia, Juniata, Mifflin, Montour, Northumberland, Snyder, Union
SHVGR	Shenango Valley Group	Crawford, Erie, Mercer
SWPAC	SW PA Commission	Allegheny, Armstrong, Beaver, Butler, Fayette, Greene, Indiana, Lawrence, Washington, Westmoreland
WPAGR	West PA Group	Clarion, Jefferson, Venango

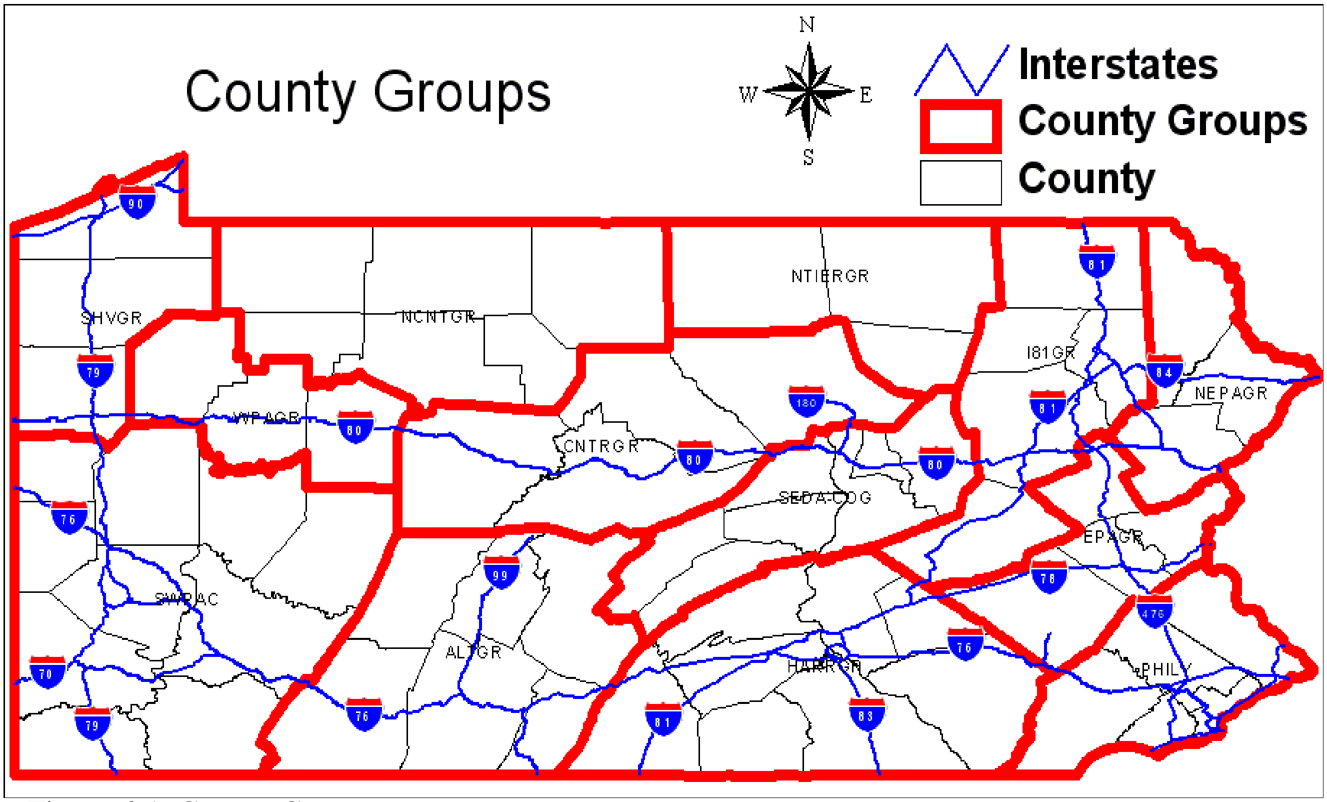


Figure 6-1. County Groups

6.2. Methodology

The earlier evaluation of candidate methods identified econometric modeling (regressions) as the preferred modeling approach for this study. In the following study, different types of regressions and model specifications were tested, including:

- Ordinary Least Squares (OLS)
- Cross-sectional Time Series OLS
- Two-stage Least Squares

The Ordinary Least Squares estimator is the optimal estimator, or the so-called Best Linear Unbiased Estimator (BLUE) of a classical linear regression model (CLR) if the CLR's assumptions are met. A CLR model for VMT is formulated as

$$VMT = c + \sum_k \lambda^k (X^k) + \varepsilon$$

Where VMT = the annual vehicle miles of travel;
c = a constant term;
λ^k = the coefficient of the kth explanatory variable;
X^k = the value of explanatory variable k;
ε_{it} = random error term.

A regular regression model generally regresses dependent variables on independently variables, forcing units of analysis (in this case, county) to have the same constant. The cross-sectional time-series fixed effect models use cross-sectional and/or time intercepts for each unit of observation. These so-called dummy variables capture factors that are not measured or unknown in the models. The factors that contribute to VMT growth may include labor force participation, vehicle availability, and spatial patterns of development. The cross-sectional time-series fixed effect models can also reduce the bias associated with the correlations between independent variables and error terms.

The general form of a cross-sectional time-series OLS regression is:

$$VMT_{it} = c + \alpha_i + \beta_t + \sum_k \lambda^k (X_{it}^k) + \varepsilon_{it}$$

Where VMT_{it} = the annual vehicle miles of travel for county *i* in year *t*;
α_i = the fixed effect for county *i*, estimated in the analysis;
β_t = the fixed effect for year *t*, estimated in the analysis;
c = a constant term;
X^k_{it} = the value of explanatory variable *k* for county *i* and year *t*;
λ^k = the coefficient of the *k*th explanatory variable;
ε_{it} = random error term for county *i* in year *t*, assumed to be normally distributed with mean zero.

The logarithmic specification of a cross-sectional time-series OLS regression is:

$$Ln(VMT_{it}) = c + \alpha_i + \beta_t + \sum_k \lambda^k (LnX_{it}^k) + \varepsilon_{it}$$

Where *Ln (VMT*$_{it}$*)* = the logarithmic form of the annual vehicle miles of travel for county *i* in year *t*;
LnX^k_{it} = the logarithmic form of the value of explanatory variable *k* for county *i* and year *t*.

In this formulation, the estimated coefficient λ^k can be interpreted as elasticity of VMT with respect to independent variables.

The difference or growth model was also tested, and it is formulated as:

$$Ln(VMT_{it}) - Ln(VMT_{i(t-1)}) = c + \alpha_i + \beta_t + \sum_k \lambda^k ((LnX_{it}^k) - (LnX_{i(t-1)}^k)) + \varepsilon_{it}$$

This formulation is used to explain the annual growth of VMT using annual growth in the independent variables.

In the two-stage least square estimation, an instrument is selected for a regressor variable that is correlated with the error term. An instrumental variable for lane mile growth in the current year could be lane mile growth over the lagged years. In this case, a two-year lag was tested. Similar to the VMT growth model above, the lane mile growth model is specified as:

$$Ln(LM_{it}) - Ln(LM_{i(t-1)}) = c + \alpha_i + \beta_t + \sum_k \lambda^k ((LnX_{it}^k) - (LnX_{i(t-1)}^k)) + \varepsilon_{it}$$

Similar to the log-linear VMT model, the lane mile model is formulated as:

$$Ln(LM_{it}) = c + \alpha_i + \beta_t + \sum_k \lambda^k (LnX_{it}^k) + \varepsilon_{it}$$

As determined from Chapter 2, the major unit of analysis is at the county level. County grouping was also tested and modeled, and results were compared with those of county-level models at the aggregate state level. In addition, the focus of the forecasting system should be four functional classifications:

- urban interstate,
- urban non-interstate,
- rural interstate, and
- rural non-interstate.

During the modeling process, statistical diagnostic tests were conducted to identify violations of OLS assumptions such as nonlinearity, heteroskedasticity, nonnormality, autocorrelation, and multicollinearity. These statistical models were also evaluated against criteria established in Chapter 2 as well as against standard regression goodness-of-fit and error statistics. These measures included adjusted R-squared, root mean squared error (RMSE), and mean absolute percentage error (MAPE).

Another checking is to compare results from this modeling effort with those from MPO travel demand forecasting models. Five counties were selected to represent three area types: (1) small rural county with a population less than 50,000, (2) medium urbanized county with a population between 50,000 and 200,000, and (3) large urbanized county with a population over 200,000. These stratifications were set up to be consistent with the HPMS area type definitions and be representative of the range of areas in Pennsylvania. A variety of factors were considered in the selection process, including availability and quality of a travel demand forecast model, geographic balance, existence of different roadway types representing the various roadway functional classifications, historical socioeconomic conditions and growth potential. For each of the five selected counties, traffic growth was projected for the planning horizon year 2030. The best statistical models developed were used to conduct traffic growth forecasts. Results from the travel demand forecasting models were reviewed for future years, and growth rates were summarized by functional classes. The traffic volume and VMT growth from statistical models were compared with results from the models. See section 6.5 for the detail.

6.3. Model Results

This section presents a brief summary of the major modeling results from a selected group of models. A variety of statistical modeling tests have been conducted, and for the brevity purposes, many tests and their results are not reported here. Detailed results are available in Appendix C. Table 6-3 shows a summary of independent variables used in different models. It should be noted that correlations among independent variables exist in these models and the size and sign of the estimated coefficients represent the interactions among independent variables. This should be kept when reading the following discussion about model results.

Table 6-3. Model Comparisons

Model Name	Variables						
	Population	Per capita Income	Households	Household Income	% Junior	% Senior	Lane Miles per capita
POP	x	X					x
HH			x	x			x
HH JrSr			x	x	x	x	x
CntyGrp HH			X	X			X
Truck HH			x	x			x

6.3.1. County-level OLS Base Models

County level OLS base models are log-linear models with fixed effects and are estimated using ordinary least squares. Dependent variables are natural logs of VMT by four categories. Independent variables consist of demographic and economic variables in natural logarithmic forms, as well as lane miles per capita. Three separate forms of the OLS based model were developed and evaluated. Model POP has population and per capita income as independent variables, while Model HH has households and mean household income as independent variables. In Model HH JrSr, percentages of population 17 years old and under and of population 65 years old and over were added to those independent variables that were already in Model HH.

As shown in Tables 6-4, 6-5 and 6-6, all models have very goodness-of-fit, as indicated by very high R squares. Population, households, and lane miles are all significant and positive, as expected. Coefficients for population and households are consistent among interstates and rural non-interstates across models. Urban non-interstates have the largest coefficients for population and households, among four facility categories and across all three forms of the models. Lane miles have consistent coefficients in the rural categories across the various forms of the models, and lower coefficients for urban interstates and lowest coefficients for urban non-interstates.

The results for income and age variables are mixed. Coefficients for income are more varied and less significant than those of population, households and lane miles. Rural interstate and urban non-interstate models have negative signs for income, contrary to expectation that VMT tends to increase with income. Similarly, coefficients for age variables are more varied and less significant across four categories of facilities. Contrary to our expectation, percent elderly population was positively related with VMT for rural non-interstates and insignificantly for rural interstate. Also unexpectedly, percent young population shows negative signs for all but rural interstates, although insignificant.

Two other income variables were also tested—percentage of households in the lowest quartile of household income distribution and percentage of households in the highest quartile of household income distribution (see Appendix C for detail). Both variables are insignificant, except for the rural non-interstate categories.

These mixed results with income and age variables may reflect a diversity of relationships between travel behaviors and these variables across the state. Clearly, rural areas in the state are dramatically different from urban areas in many ways, including the lack of public transit and longer trip lengths. These results indicate that rural VMT may have a different relationship with income and age variables than urban VMT.

Table 6-4. OLS Base Models — Model POP

Dependent Var=LN(VMT)	Rural Interstates		Rural Non-Interstates		Urban Interstates		Urban Non-Interstates	
Adjusted R^2		99.1		97.6		99.7		99.6
N		434		660		421		544
	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
Constant	-62.062	-11.11	4.309	0.63	-45.659	-5.74	-35.761	-5.32
LN (Population)	1.231	8.88	1.2606	6.44	1.23078	27.5	1.90763	48.99
LN (Per Capita Income)	-0.1121	-0.7	0.3606	1.94	0.2062	0.98	-0.6681	-3.6
LN (Lane Miles Per Capita)	0.99697	42.7	1.3765	14.41	0.53263	11.4	0.15485	6.58
Year	0.03766	10.51	0.001285	0.31	0.02603	5.4	0.019822	4.85

* County dummy coefficients are omitted for brevity. See Appendix C for details.

Table 6-5. OLS Base Models— Model HH

Dependent Var=LN(VMT)	Rural Interstates		Rural Non-Interstates		Urban Interstates		Urban Non-Interstates	
Adjusted R^2		99.1		97.6		99.7		99.6
N		434		660		421		544
	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
Constant	-52.459	-12.93	9.838	2.07	-37.766	-6.28	-12.264	-2.56
LN (Households)	1.422	9.88	1.5046	7.44	1.2391	27.33	1.92057	49.25
LN (Mean Household Income)	-0.2743	-1.75	0.2075	1.16	0.1663	0.79	-0.6862	-3.82
LN (Lane Miles Per Capita)	0.99463	43.81	1.38995	14.9	0.53123	11.33	0.12889	5.45
Year	0.033239	11.39	-0.001631	-0.48	0.022734	5.84	0.009236	2.96

* County dummy coefficients are omitted for brevity. See Appendix C for details.

Table 6-6. OLS Base Models— Model HH JrSr

Dependent Var=LN(VMT)	Rural Interstates		Rural Non-Interstates		Urban Interstates		Urban Non-Interstates	
Adjusted R^2		99.1		97.8		99.7		99.7
N		434		660		421		544
	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
Constant	-63.74	-9.89	26.425	3.69	-28.875	-3.5	-11.332	-1.61
LN (Households)	1.3415	8.91	1.2152	5.93	1.5244	6.52	1.7685	8.41
Pop17 (% of Pop<17 yrs)	2.108	2.26	-1.3825	-1.49	-2.006	-1.79	-0.559	-0.55
Pop65+ (% of Pop>65+ yrs)	0.599	0.46	9.117	6.09	-4	-2.2	-2.995	-2.02
LN (Mean Household Income)	-0.3587	-2.23	0.4663	2.61	0.1956	0.89	-0.6987	-3.77
LN(Lane Miles Per Capita)	0.9923	43.83	1.30628	14.4	0.51138	10.15	0.10233	4.04
Year	0.039523	9.8	-0.010259	-2.3	0.016859	3.21	0.00994	2.26

* County dummy coefficients are omitted for brevity. See Appendix C for details.

6.3.2. County-level OLS Difference Models

As described in the methodology section, county-level OLS difference models are difference-in-natural log-linear models with fixed effects and estimated using ordinary least squares. Dependent variables are differences in natural logs of VMT by four categories between year t and year t-1. Independent variables consist of demographic and economic variables, as well as lane miles per capita, all in the form of differences in natural logs between year t and year t-1. These differences are essentially growth in the logarithmic form. Similar to county-level OLS base models, the county-level difference models tested the same combination of independent variables. Tables 6-7 and 6-8 show summaries of estimation results for the household (HH) model and the HH JrSr model based on households, junior and senior population proportions.

As can be seen from the Tables 6-7 and 6-8, the models do not have as high goodness-of-fit measures as the county-level models. The R^2 values are much lower, which is not surprising, as similar results have been reported in the previous studies using difference models. There are some similarities and differences in the coefficient estimation results. The coefficients for difference in lane miles per capita are consistent with those for lane miles per capita in the base models and highly significant. However, households and household income difference variables are mostly insignificant or in the wrong sign. The results for percent young and percent elderly population are also varied, like the base models.

Table 6-7. OLS Difference Models - Model HH

Dependent Var=Diff LN(VMT)	Rural Interstates		Rural Non-Interstates		Urban Interstates		Urban Non-Interstates	
Adjusted R^2		78.9		40.3		25		6.3
N		390		594		378		486
	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
Constant	0.0191	0.71	-0.03736	-1.14	0.02839	0.86	0.03152	0.96
Diff LN (Households)	0.2307	0.25	0.2261	0.27	0.843	0.68	1.007	0.93
Diff LN (Mean Household Income)	-0.2157	-0.95	0.5792	2.48	0.3599	1.16	-0.8725	-3.22
Diff LN (Lane Miles Per Capita)	0.99638	36.44	1.81149	19.03	0.57852	11.6	0.17826	6.32

* County dummy coefficients are omitted for brevity. See the appendix section for details.

Table 6-8. OLS Difference Models - Model HH JrSr

Dependent Var=Diff LN(VMT)	Rural Interstates		Rural Non-Interstates		Urban Interstates		Urban Non-Interstates	
Adjusted R^2		79.3		42.8		24.7		11.6
N		390		594		378		486
	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
Constant	-0.5042	-1.87	-1.0917	-4.06	-0.0585	-0.19	1.2415	4.43
Pop17 (% of Pop<17 yrs)	1.7419	2.92	2.705	4.93	0.6563	0.87	-3.2193	-5.11
Pop65+ (% of Pop>65+ yrs)	0.828	0.55	3.102	2.12	-0.503	-0.27	-3.329	-2.11
Diff LN (Households)	-0.758	-0.77	-1.355	-1.46	0.423	0.32	2.585	2.3
Diff LN (Mean Household Income)	-0.3188	-1.4	0.3693	1.59	0.3254	1.04	-0.625	-2.33
Diff LN (Lane Miles Per Capita)	0.98419	35.83	1.75303	18.56	0.58859	11.2	0.16173	5.87

* County dummy coefficients are omitted for brevity. See the appendix section for details.

6.3.3. County-Group OLS Base Models

Like county-level models, county group OLS base models are log-linear models with fixed effects and estimated using ordinary least squares. The major difference lies in the unit of analysis, which is aggregated at the county group level as defined previously (Table 6-2). Dependent variables are natural logs of VMT by four categories. Independent variables consist of demographic and economic variables, as well as lane miles per capita, in natural logarithmic forms.

Like county-level models, all county-group models have excellent goodness-of-fit, as indicated by very high R squares in Table 6-9. Households and lane miles are all significant with positive sign, as expected. Unlike county-level models, coefficients for households are not consistent among interstates and rural non-interstates across models. Rural non-interstates have the largest coefficients for households, among the four facility categories and across models. Lane miles have a wide range of coefficients across the models, rural non-interstates have the highest coefficients, and urban non-interstates the lowest coefficients.

Again, income and age variables have varied results. Rural and urban non-interstate models have negative signs for income, contrary to our expectation that VMT tends to increase with income. Similarly, coefficients for age variables are more varied and less significant across four categories of facilities (not shown here). Contrary to our expectation, percent elderly population was positively related with VMT for rural interstate and non-interstate facilities. Also unexpectedly, percent young population shows negative signs for urban non-interstates and although insignificant, for rural interstates.

Table 6-9. County Group Models - Model HH

Dependent Var=LN(VMT)	Rural Interstates		Rural Non-Interstates		Urban Interstates		Urban Non-Interstates	
Adjusted R^2	98.9		98.7		99.8		99.9	
N	110		130		120		130	
	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
Constant	-9.203	-4.59	-10.57	-4.01	-2.037	-0.64	0.318	0.15
LN (Households)	1.7318	7.46	4.0981	12.26	1.6203	5.15	2.2667	8.51
LN (Mean Household Income)	1.5384	10.55	-0.2818	-2.01	0.7692	3.82	-0.3778	-2.32
LN (Lane Miles Per Capita)	1.00868	23.28	3.5944	14.8	0.90262	9.65	0.30991	5.64

* County group dummy coefficients are omitted for brevity. See the appendix section for details.

6.4. Evaluation

As shown above, all county-level base models and county-group models have superior goodness-of-fit values, as demonstrated by near perfect adjusted R^2 values. Additional measures to evaluate these models, including regression diagnostics, were also used.

In addition, Mean Absolute Percentage Error (MAPE) was used to evaluate the model errors. The MAPE measures how the fitted values are deviated from the observations. Table 6-10 summarized the results from different models. Overall, these models have very low errors.

Table 6-10. Mean Absolute Percentage Errors for Different Models

	Rural Interstates	Rural Non-Interstates	Urban Interstates	Urban Non-Interstates
Model POP	4.72	6.31	5.57	5.41
Model HH	4.70	6.20	5.55	5.26
Model HH JrSr	4.62	6.00	5.43	4.80
County Group Model HH	4.14	4.39	4.45	3.81
Truck Model HH	5.55	6.20	5.87	4.74

Another way of evaluating the models is to examine the error distributions of the fitted versus observed values. Figures 6-2 to 6-5 show the cumulative percent error distributions by facility categories. As can be seen from these figures, more than ninety percent of the observations fall within the error range of –10% to +10%. This is a clear indication for a good fit. Three county-level models—Model POP, HH, and HH JrSr—almost have identical error distributions. County group models show slightly better results than county-level models, because the steeper slopes of their error distribution curves indicate lower errors.

It should be noted that all model results reflect the quality and nature of the data. Chapter 5 describes some major characteristics of VMT and socioeconomic data. In particular, the 2003 VMT re-classifications have dramatically shifted VMT among different categories. These dramatic VMT changes reflect primarily reclassification of lane miles and associated traffic volumes, while changes in travel behavior and socioeconomic variables were incremental. Although lane miles were introduced in the models to account for VMT changes, lane miles cannot fully account for the dramatic shifts in VMT. This is because lane mile reclassification is not random and high-volume facilities tended to be affected much more than low-volume facilities in the re-classification process. In many cases, when roads were re-classified from a rural to urban category, they tended to be in or close to urban areas initially and carry much traffic. This bias toward high-volume facilities presents a difficulty for lane miles to account for VMT shifts. This is the primary reason why the fitted models still have errors, some even outside the error range of –10% to +10%.

The research next examined forecasting results from these models and if the forecasting results meet expectations.

6.5. Forecasting

Selected models were used to forecast VMT for 2010, 2020, and 2030. VMT growth rates were calculated for periods of 2003-2010, 2010-2020, and 2020-2030. Table 6-11 summarizes annual growth rates by four different models, in comparison with 1994-2003 growth rates. See Appendix C for detailed results at the county level. Figures 6-7 and 6-8 show both 1994-2003 VMT growth and forecasted 2003-2030 VMT growth.

Table 6-11. VMT Annual Growth Rates Forecasted by Different Models

Model	Facility Category	1994-03	2003-10	2010-20	2020-30
Model: Pop	Rural Interstates	4.09%	3.80%	3.82%	3.83%
	Rural Non-Interstates	-0.87%	0.52%	0.52%	0.52%
	Urban Interstates	4.12%	3.13%	3.19%	3.25%
	Urban Non-Interstates	1.73%	1.76%	1.92%	2.07%
	Total	1.54%	1.93%	2.11%	2.31%
Model HH	Rural Interstates	4.09%	3.72%	3.40%	2.95%
	Rural Non-Interstates	-0.87%	0.48%	0.24%	-0.13%
	Urban Interstates	4.12%	3.03%	2.88%	2.62%
	Urban Non-Interstates	1.73%	1.41%	1.07%	0.57%
	Total	1.54%	1.74%	1.58%	1.31%
Model HH JrSr	Rural Interstates	4.09%	3.75%	4.15%	3.74%
	Rural Non-Interstates	-0.87%	0.66%	2.99%	3.47%
	Urban Interstates	4.12%	3.11%	1.21%	0.69%
	Urban Non-Interstates	1.73%	1.54%	0.12%	-0.22%
	Total	1.54%	1.86%	1.66%	1.76%
Model CntyGrp HH	Rural Interstates	4.09%	2.11%	2.15%	2.10%
	Rural Non-Interstates	-0.87%	0.91%	0.09%	-1.09%
	Urban Interstates	4.12%	1.39%	1.31%	1.12%
	Urban Non-Interstates	1.73%	0.76%	0.42%	-0.13%
	Total	1.54%	1.07%	0.72%	0.23%

Forecast annual growth rates vary considerably with different models, although they are all in normal historical ranges as shown in Tables 5-1 and 5-2. These growth rate differences show relatively small impact on VMT growth forecasts in the short term (2003-2010), but lead to dramatically different long range VMT forecasts due to compounding.

The variation in the forecasted values has to do with the growth forecasting of independent variables in different models. For example, per capita income has the highest growth rates among independent variables (as shown in Figure 5-12), and is a major cause of driving up the VMT growth rates.

General consensus exists that overall VMT growth will be moderating over the next three decades because many driving forces for VMT growth have shown the signs of stabilization. Household growth rates are decreasing, and the rate of household size decrease is slowing. The population is aging, and the elderly share will pick up rapidly in 2010 and after. The elderly cohorts tend to travel less than the general population, as shown in previous Nationwide Personal Transportation Surveys. Labor force participation rates and vehicle availability have reached a stabilization range. While real income has increased significantly and will likely continue to do so, the household travel spending has remained relatively constant over time. It can be argued that the importance of real income growth in travel will be smaller in the next three decades than in previous decades (Polzin et al. 2003).

Although VMT growth has been over 3 percent for the nation as a whole, nationwide VMT growth has been forecasted to be lower. A 2002 US DOT report cited an annual growth rate of 2.08 percent through 2020. Since Pennsylvania has historically grown slower in travel than the national average, it would be reasonable to expect a lower overall growth rate in the future.

Considering VMT moderation in the future and growth magnitude, we can conclude that Model Pop is not a good candidate for our VMT forecasting system. Model Pop generates growth rates that are increasing over time. The magnitude of growth rates is also higher than expected.

Model HH appears to produce forecasts that are consistent with expectations. Forecast growth rates are moderating across all facilities over time, and the overall growth rates seem to be in the expected range. One may argue that forecasted annual growth rates for interstate categories appear to be too high. This is certainly a manifestation of historical VMT data inputs to the model estimation. As shown in Table 5-2, annual growth rates are over 3 percent for rural interstate VMT in 6 out of 9 years and for urban interstate VMT in 5 years. Overall annual growth rates averaged 4.1 percent for rural interstates and 4.8 percent for urban interstates during the period 1994-2003.

Model HH JrSr has some irregularities in the VMT growth forecasting results, which are related to irregularities in model coefficients. As described in the model results section, for example, percent elderly population was positively related with VMT for rural non-interstates. Although overall VMT growth rates are in the normal range, the forecasting patterns and trend irregularities render this model less reliable.

County group models produce significantly lower VMT growth rates than the other three model sets. Although all county group models show declining growth rates in the future, there are some troubling items. The decline of rural non-interstate VMT is too steep, and the negative growth for the 2020-2030 period is particularly too steep beyond expectations and the literature.

County groups were developed to reflect interactions among jurisdictions and at the corridor level. It was hypothesized that these interactions are particularly common among interstate/freeway categories and useful for forecasting interstate/freeway VMT. It would be less useful for non-interstate categories to have county group formulation. Therefore, county-group non-interstate models may be less reliable. Comparing the interstate growth rates from Model HH and Model County Groups, we see the differences that are not trial, particularly in the short term. Because the statewide interstate VMT growth rates over the most recent decade are over 4 percent (see Table 5-2), the forecasted growth rates of 1.4% and 2.1% for the 2003-2010 period seem particularly low.

At the statewide level, the household models appear to produce the best VMT growth forecasting among the four models, while county-group models do offer a means of cross-checking.

Figures 6-8 through 6-15 show the geographic distribution of forecasted annual VMT growth rates by facility category, based on the county group-level model and Figures 6-16 through 6-19 based on the county-level HH model. All maps illustrate the pattern of high VMT growth in the east and south-central regions and low growth in the west and north regions. This pattern is consistent with the regional divide of socioeconomic growth as described in Chapter 3.

We also compare the modeling results with VMT growth rates from metropolitan travel demand models and Table 6-12 summarizes these results. Overall, projected VMT growth rates from the household model are higher than those from travel demand models. In some categories, the forecasted growth rates are close. The growth rate patterns are similar in that interstate categories have higher growth rates than non-interstate categories.

Many factors contribute to the difference between the household model developed in this study and travel demand models. The VMT models developed in this project are dynamic in the sense that they incorporate temporal changes as a driving force behind VMT growth over the years. Trends embedded in these panel data were captured in the models and carried over the future forecasting horizons. Most traditional travel demand models are static and validated against a single base year data, and no longitudinal changes are incorporated in the model to affect the future forecasting. In other words, travel behavior in 2030 is assumed to be the same as that in 2000 in most travel demand models. For example, past or current survey data are used to develop trip length distribution, which is then carried over to the planning horizon year. To the extent that trip length has increased over the years, the fixed trip length assumption makes the VMT growth smaller than it should be.

Traditional travel demand models have some other deficiencies that may lead to underestimation in VMT growth. One major deficiency, for example, is the models' failure to account for the feedback from transportation system performance to land development patterns. In traditional travel demand models, the relationship between land use and transportation system is one-way. Land use and spatial patterns of land development are simply input to the models, affecting travel demand and transportation system performance. In realty and theory, land use and transportation system is a two-way relationship. Transportation system performance shapes the land development patterns in the long run.

Table 6-12. Growth Rates from HH Regression Model and Travel Demand Models

Region Type	County	Growth Rates 2000/2002---2030							
		Base Year	Pop	HH	Emp	VMT Urb Int	VMT Rur Int	VMT Urb Non-Int	VMT Rur Non-Int
Growth Rates from TDM									
Rural < 50,000 (Growing)	***Perry***	2002	0.79%	0.79%	1.20%			**1.43%**	**1.20%**
Rural < 50,000 (Declining)	N/A								
Small Urban 50,000 - 200,000 (Growing)	***Centre***	2000	1.59%	1.71%	1.77%	**2.97%**	**3.63%**	**0.29%**	**0.54%**
Small Urban 50,000 - 200,000 (Declining)	***Beaver***	2002	0.11%	0.58%	0.04%	**0.94%**		**0.20%**	**0.46%**
Urban > 200,000 (Growing)	***Lancaster***	2002	0.82%	0.83%	1.70%	**1.58%**	**1.77%**	**1.50%**	**0.46%**
Urban > 200,000 (Declining)	***Allegheny***	2002	0.03%	0.46%	0.16%	**0.87%**		**-0.03%**	**0.23%**
Growth Rates from Regressions	**County**								
Rural < 50,000 (Growing)	***Perry***	2002	1.10%	1.15%	1.03%			**2.52%**	**0.18%**
Rural < 50,000 (Declining)	N/A								
Small Urban 50,000 - 200,000 (Growing)	***Centre***	2000	0.80%	0.88%	1.38%	**3.21%**	**3.48%**	**1.63%**	**0.32%**
Small Urban 50,000 - 200,000 (Declining)	***Beaver***	2002	0.17%	0.16%	0.95%	**2.64%**		**0.30%**	**0.12%**
Urban > 200,000 (Growing)	***Lancaster***	2002	0.89%	1.03%	0.92%	**3.28%**	**3.70%**	**2.13%**	**0.34%**
Urban > 200,000 (Declining)	***Allegheny***	2002	-0.15%	-0.17%	0.75%	**2.42%**		**-0.44%**	**0.10%**

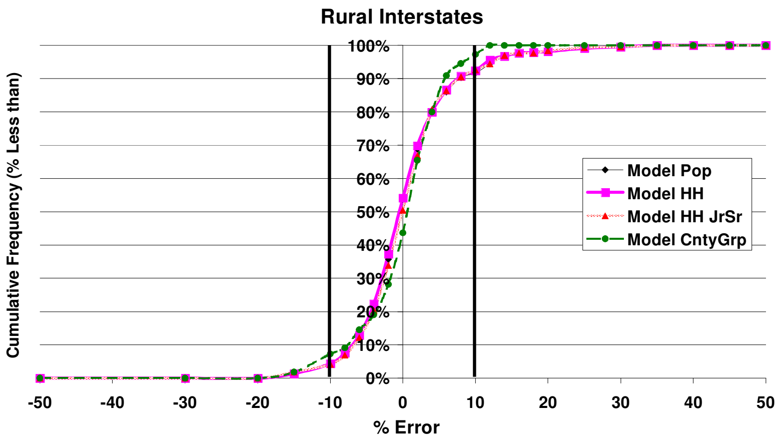
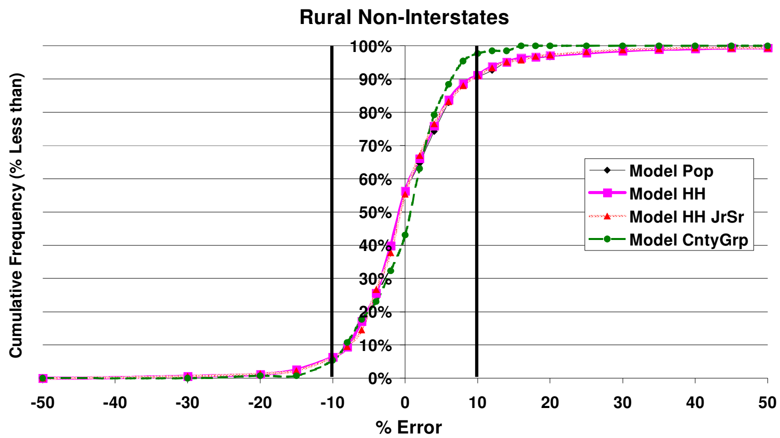


Figure 6-2.
Models Percent Error
Distribution for
Rural Interstates

Figure 6-3.
Models Percent Error
Distribution for
Rural Non-Interstates



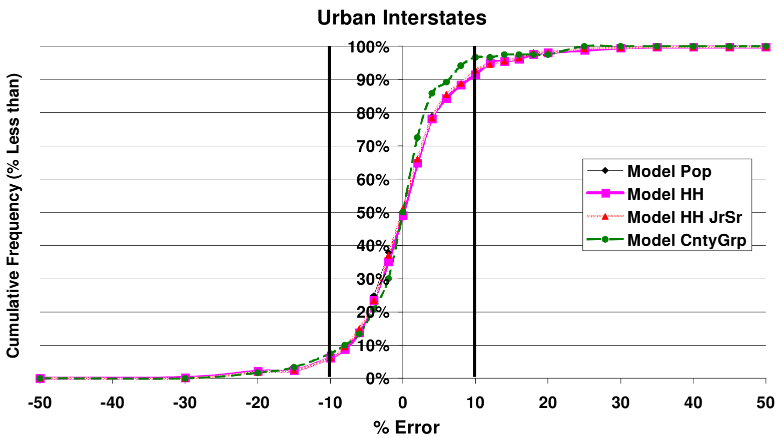
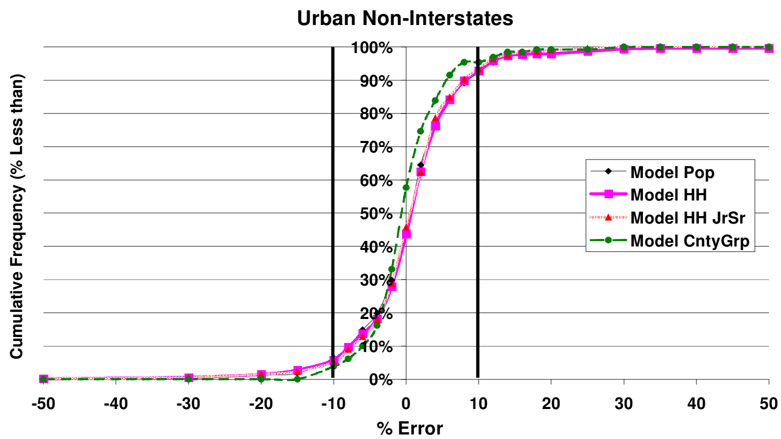


Figure 6-4.
Models Percent Error
Distribution for
Urban Interstates

Figure 6-5.
Models Percent Error
Distribution for
Urban Non-Interstates



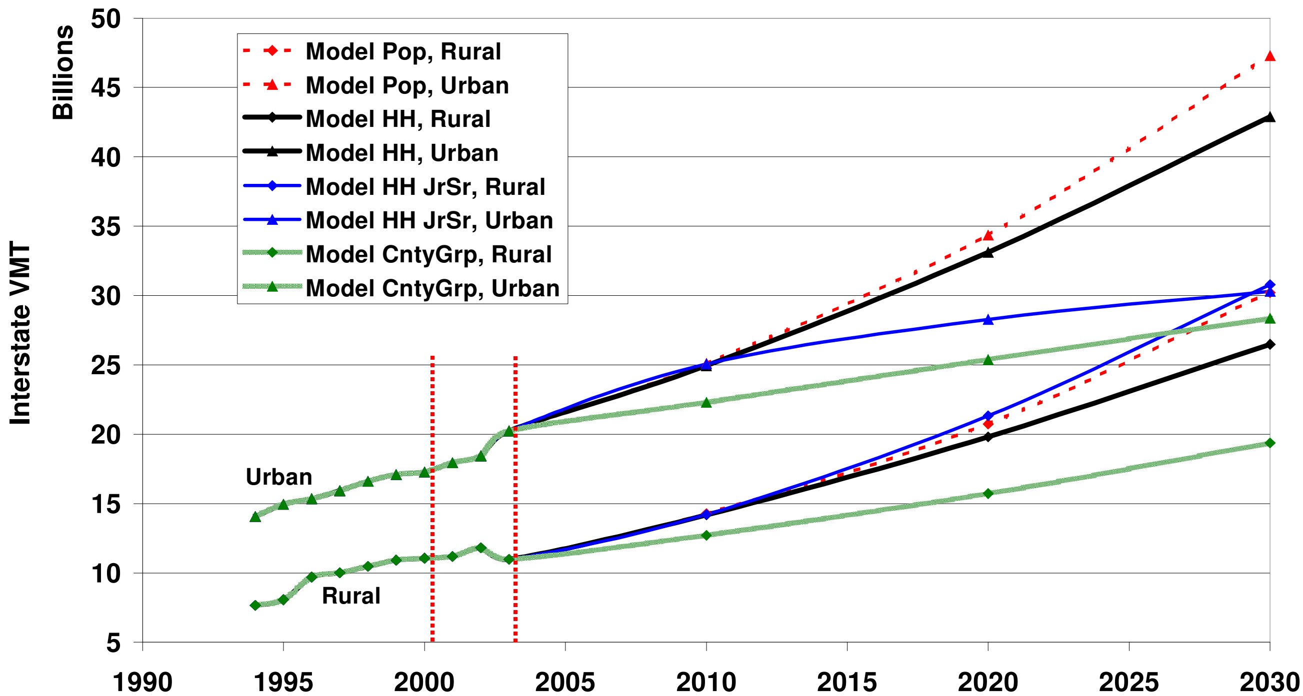


Figure 6-6. Models Interstate VMT Forecasts

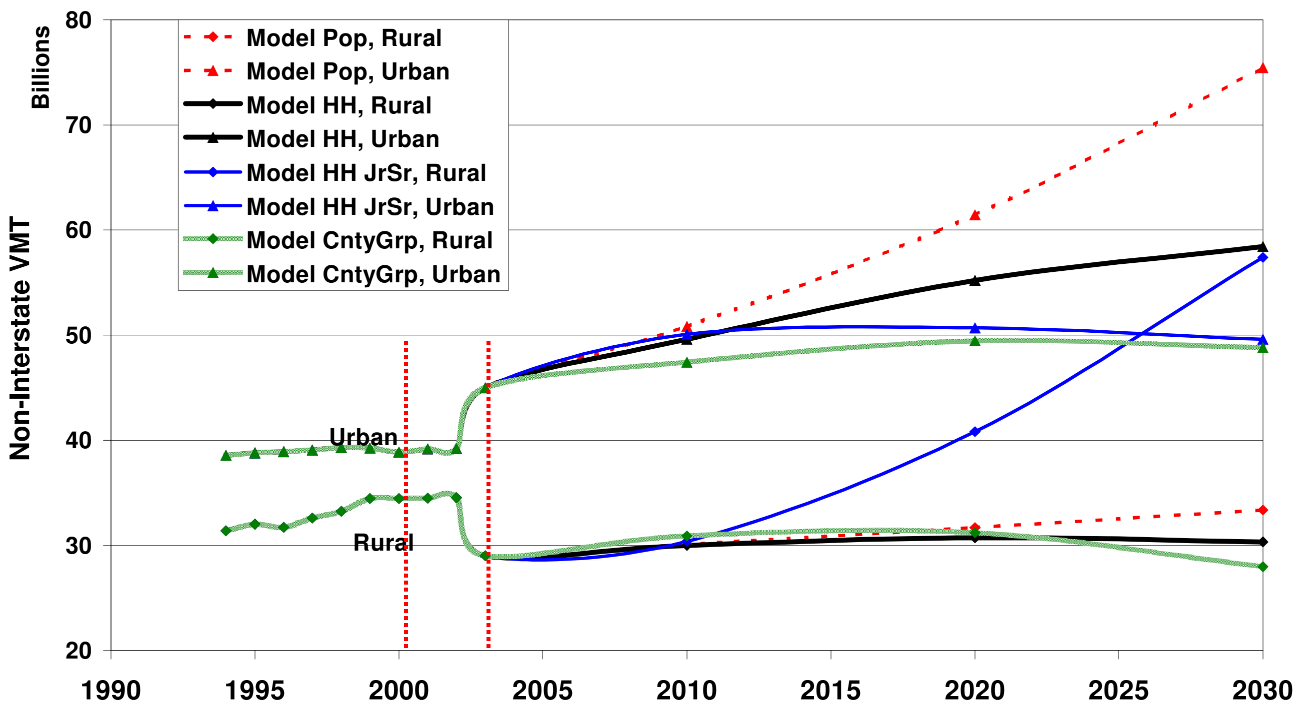


Figure 6-7. Models Non-Interstate VMT Forecasts

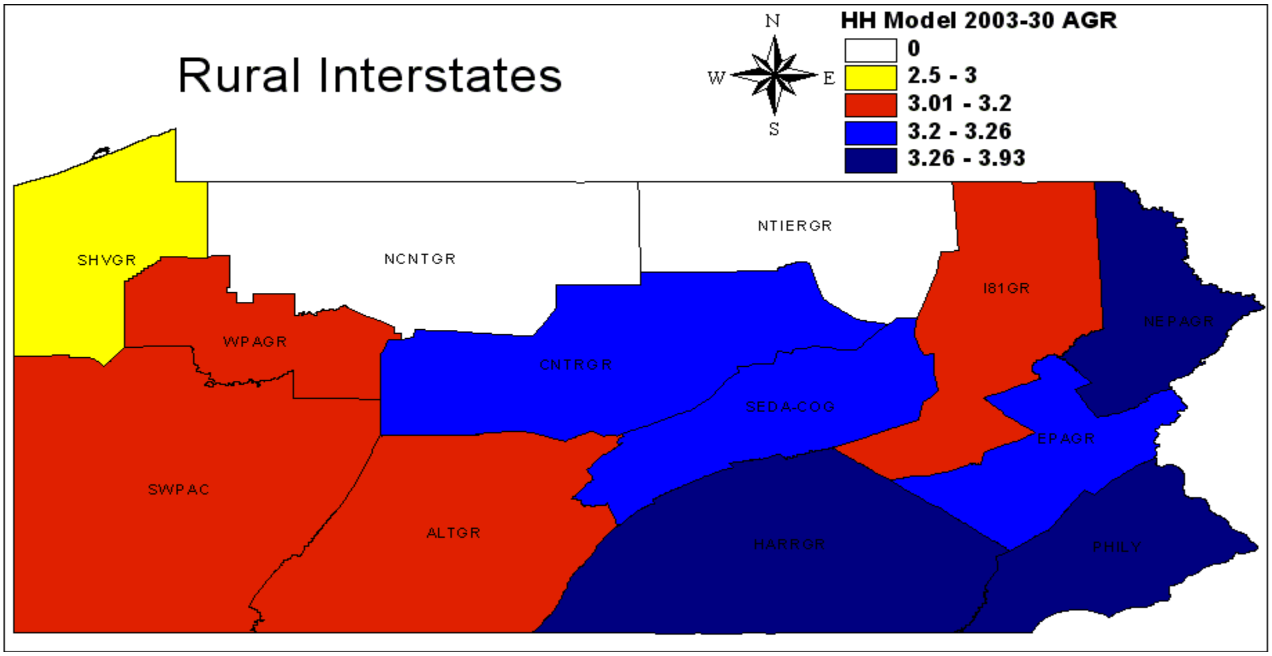


Figure 6-8. Rural Interstate VMT 2003-2030 Annual Growth Rates

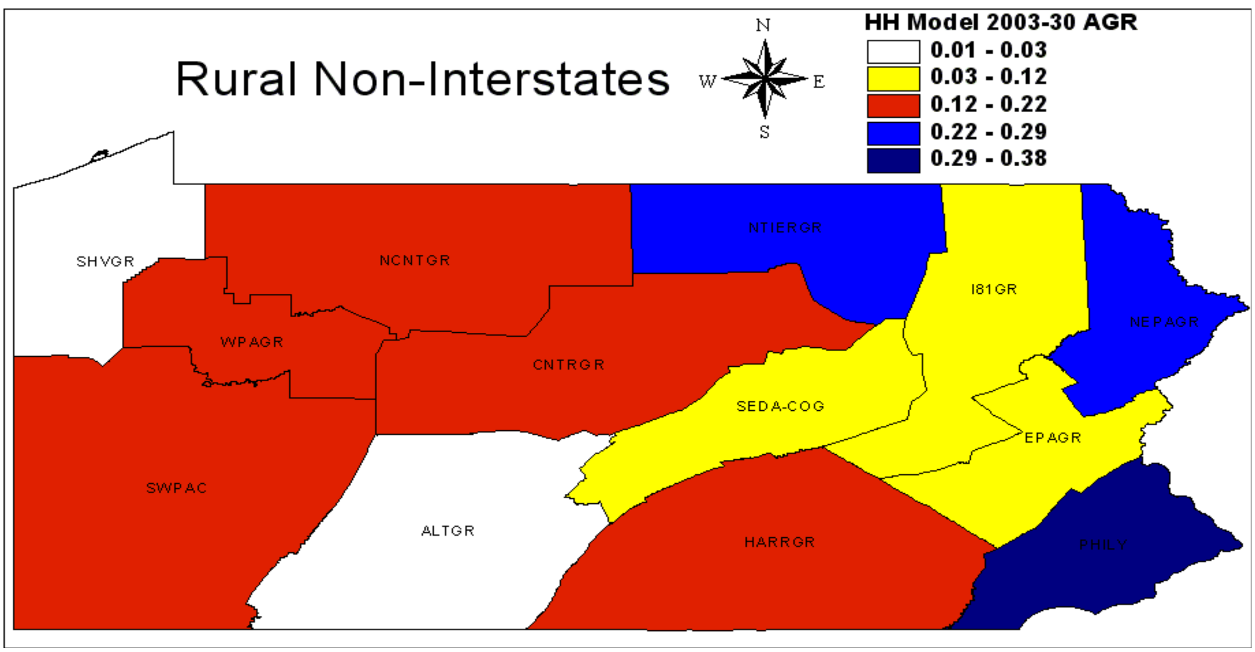


Figure 6-9. Rural Non-Interstate VMT 2003-2030 Annual Growth Rates

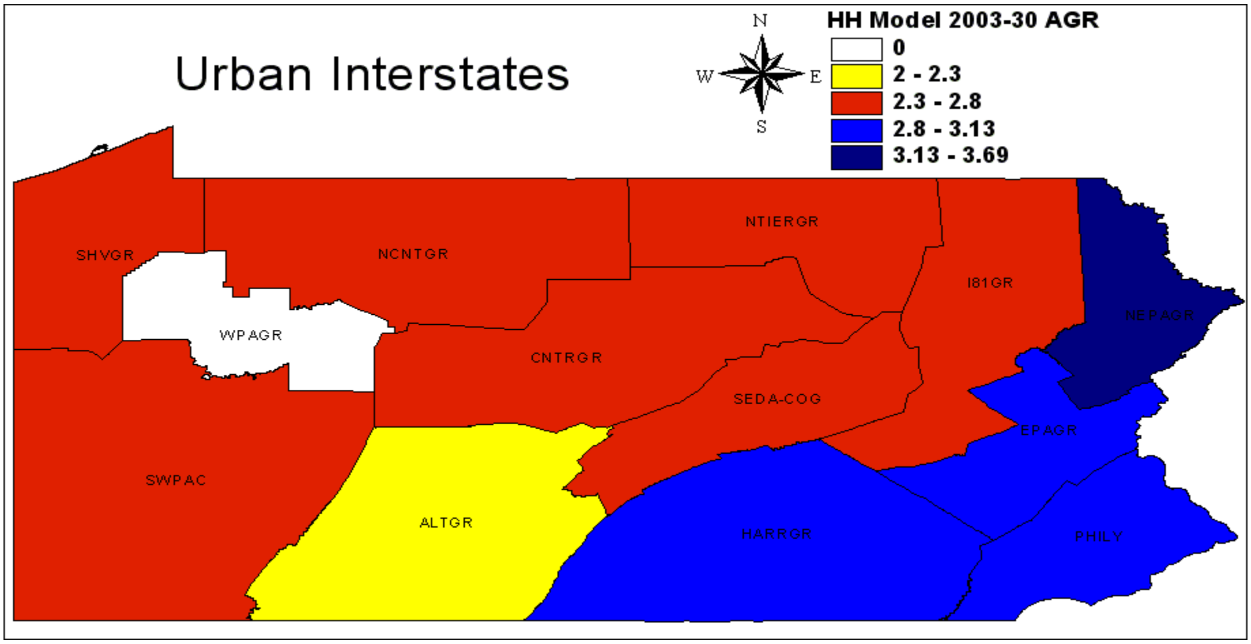


Figure 6-10. Urban Interstate VMT 2003-2030 Annual Growth Rates

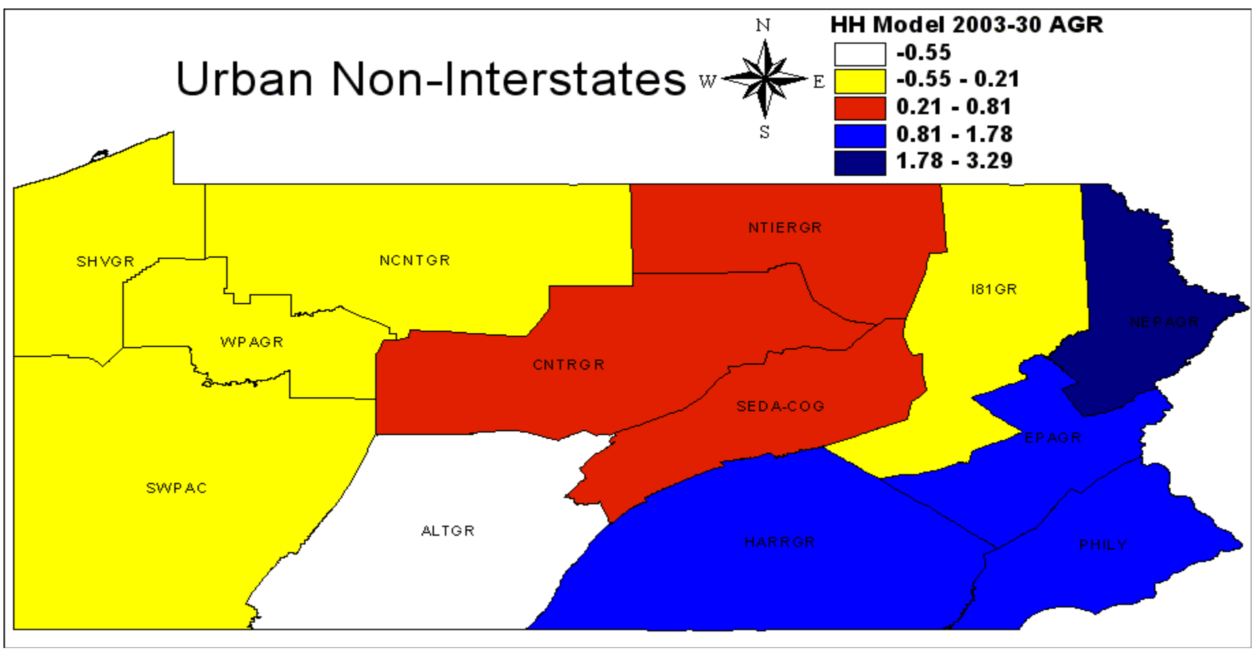


Figure 6-11. Urban Non-Interstate VMT 2003-2030 Annual Growth Rates

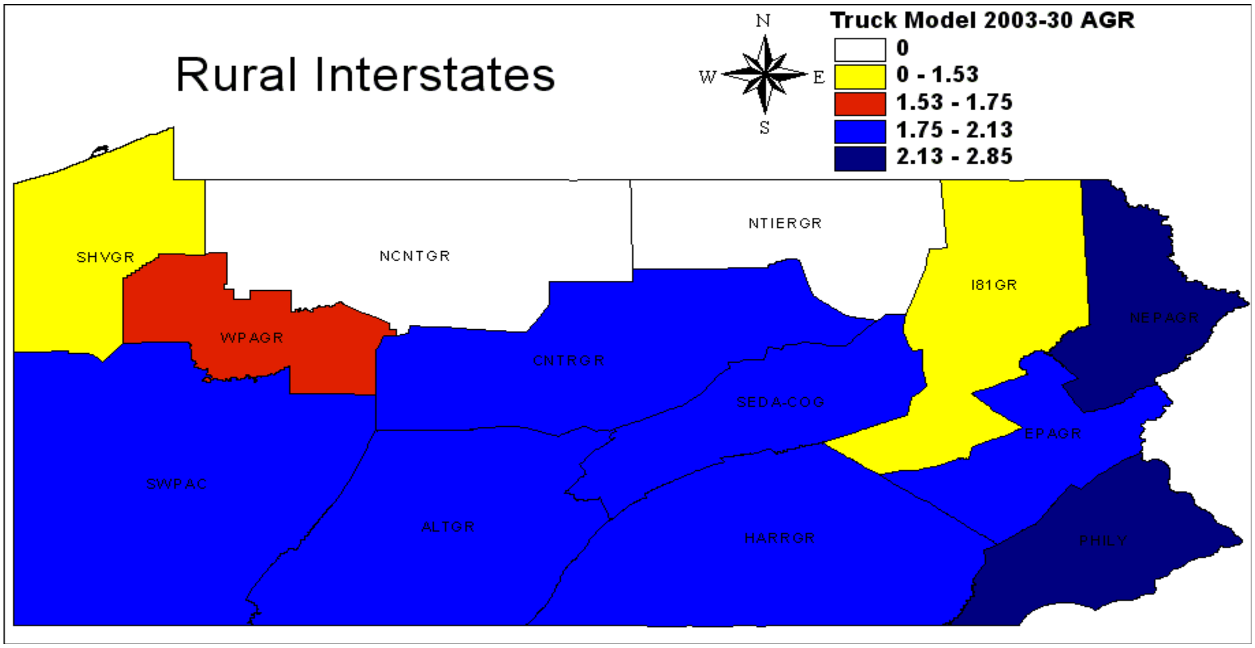


Figure 6-12. Rural Interstate Truck VMT 2003-2030 Annual Growth Rates

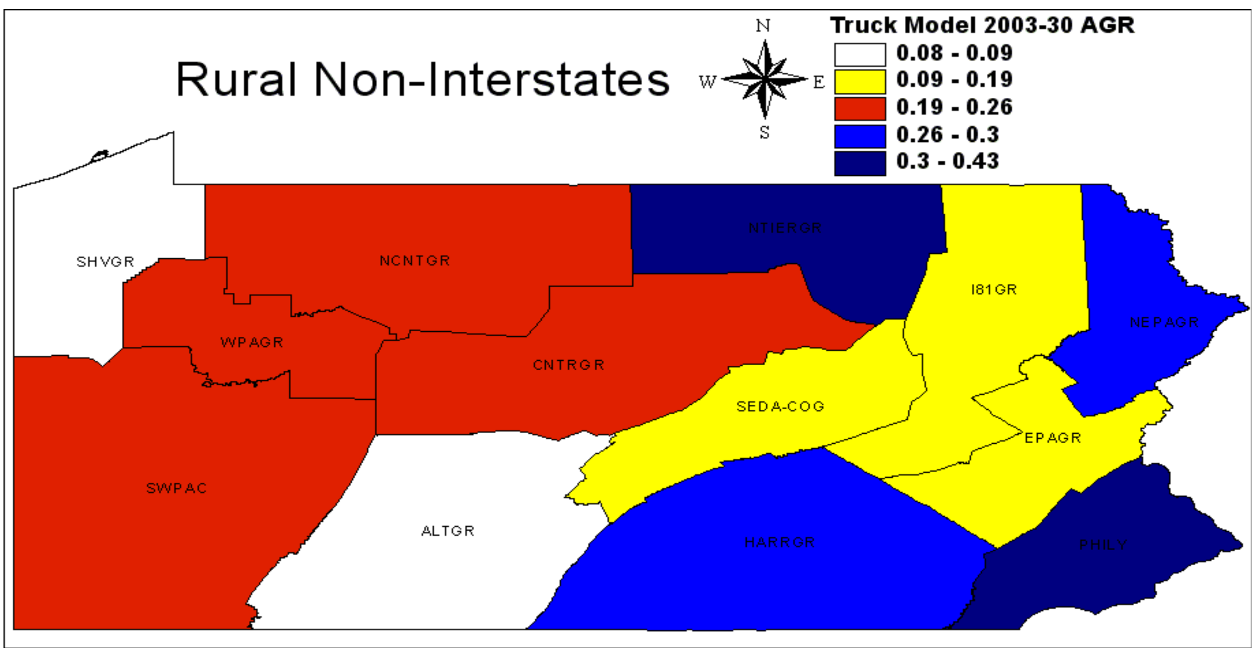


Figure 6-13. Rural Non-Interstate Truck VMT 2003-2030 Annual Growth Rates

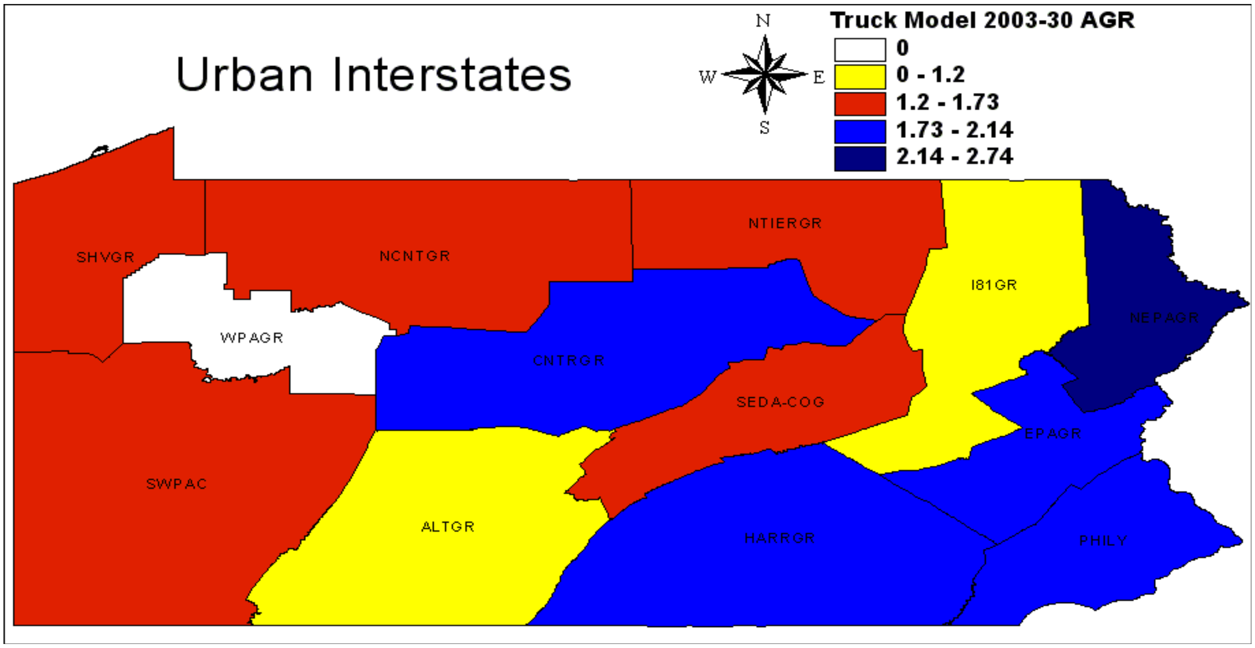


Figure 6-14. Urban Interstate Truck VMT 2003-2030 Annual Growth Rates

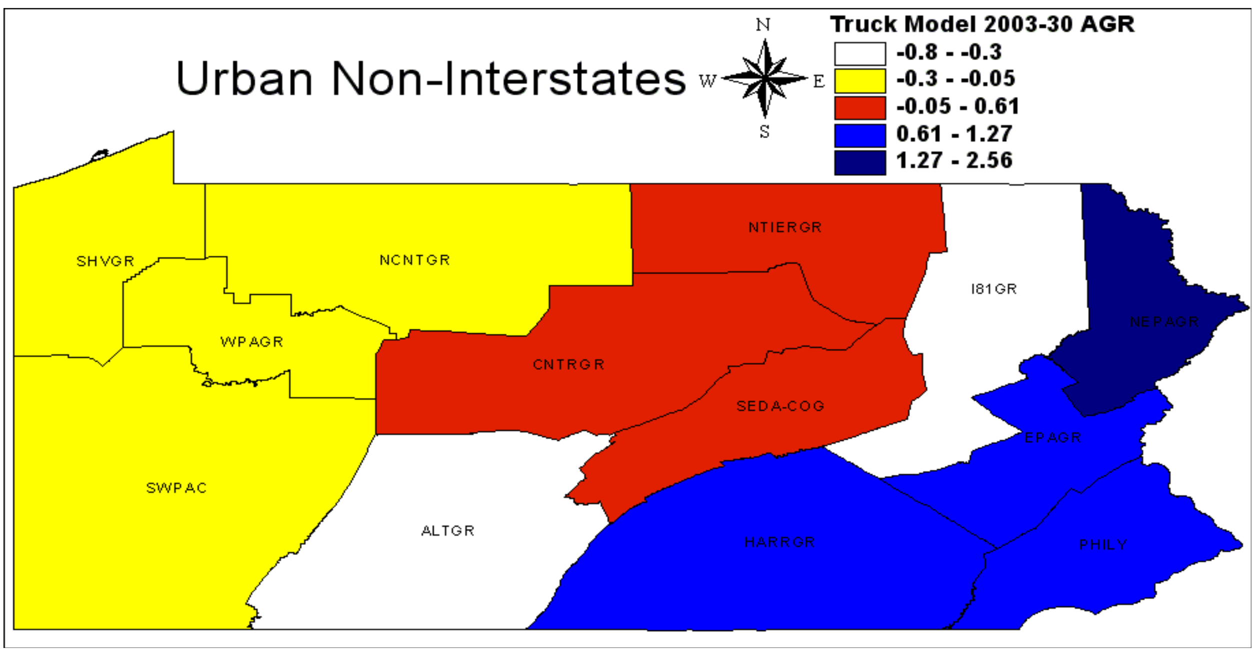


Figure 6-15. Urban Non-Interstate Truck VMT 2003-2030 Annual Growth Rates

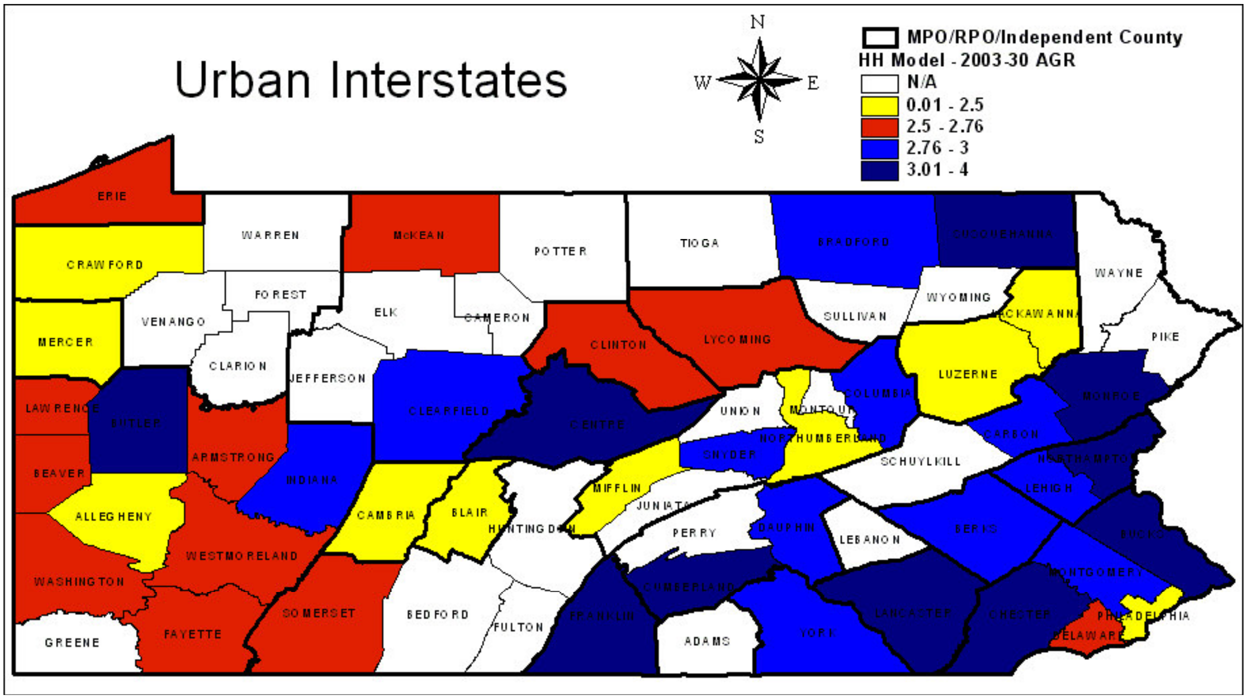


Figure 6-16. Urban Interstate VMT 2003-2030 County Annual Growth Rates

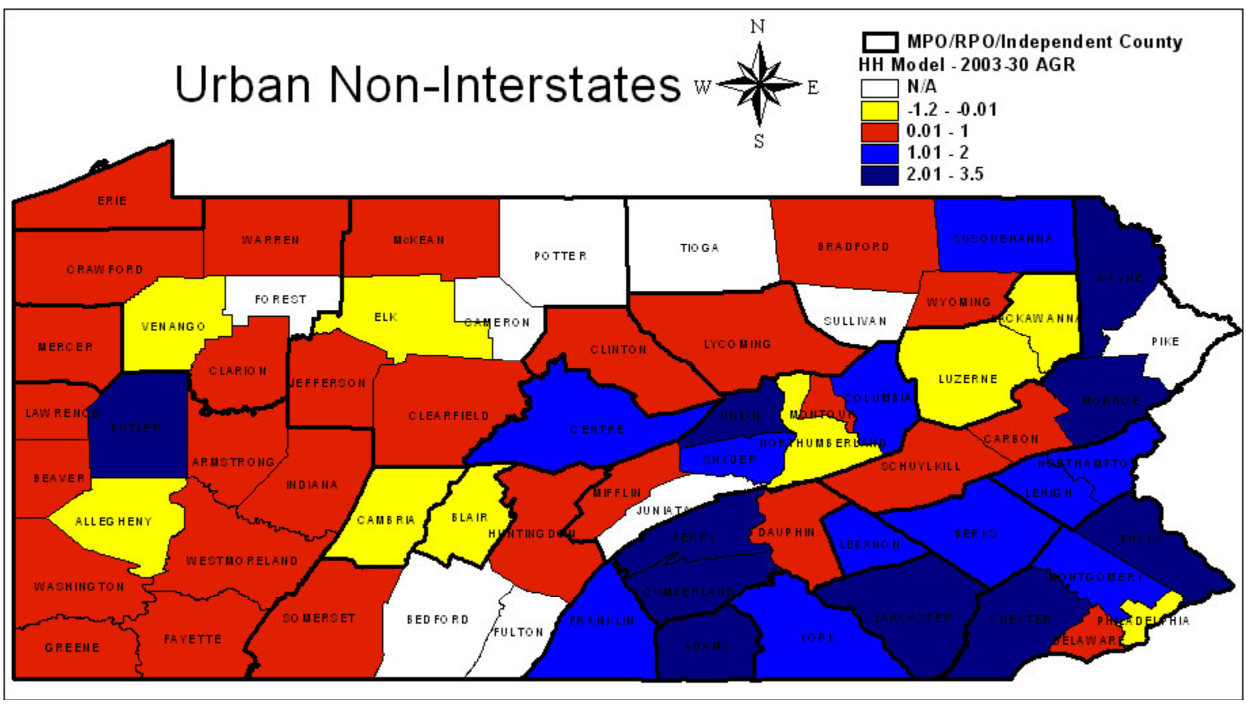


Figure 6-17. Urban Non-Interstate VMT 2003-2030 County Annual Growth Rates

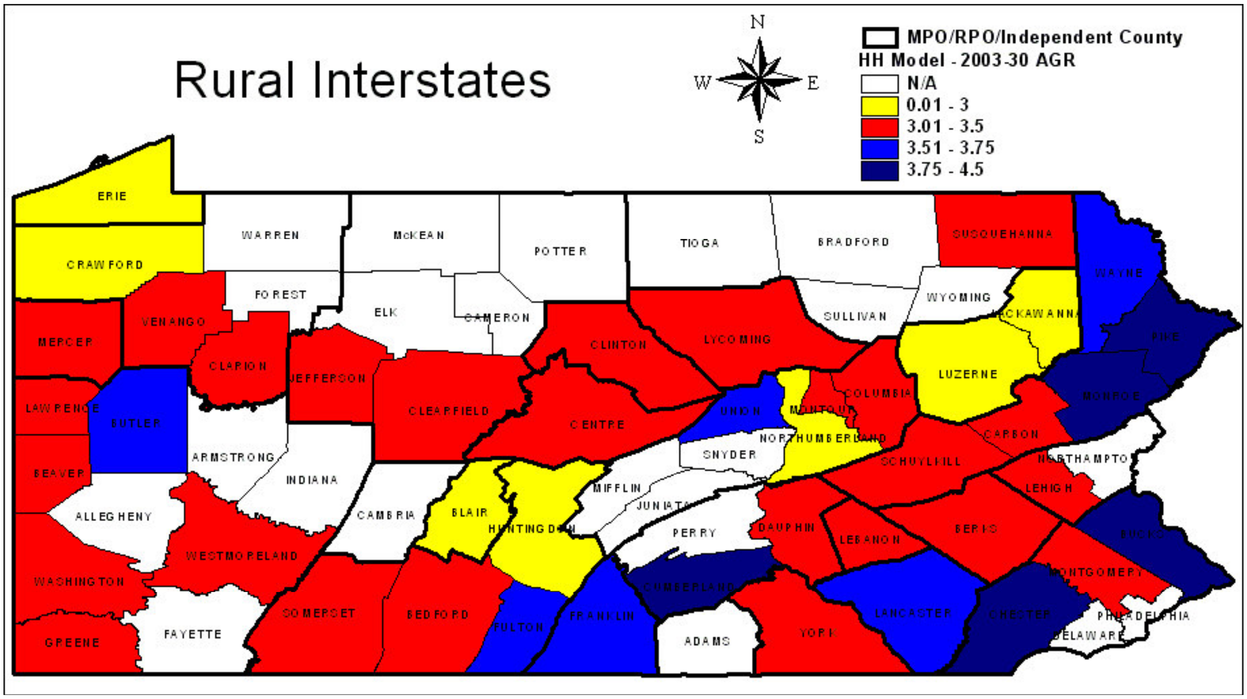


Figure 6-18. Rural Interstate VMT 2003-2030 County Annual Growth Rates

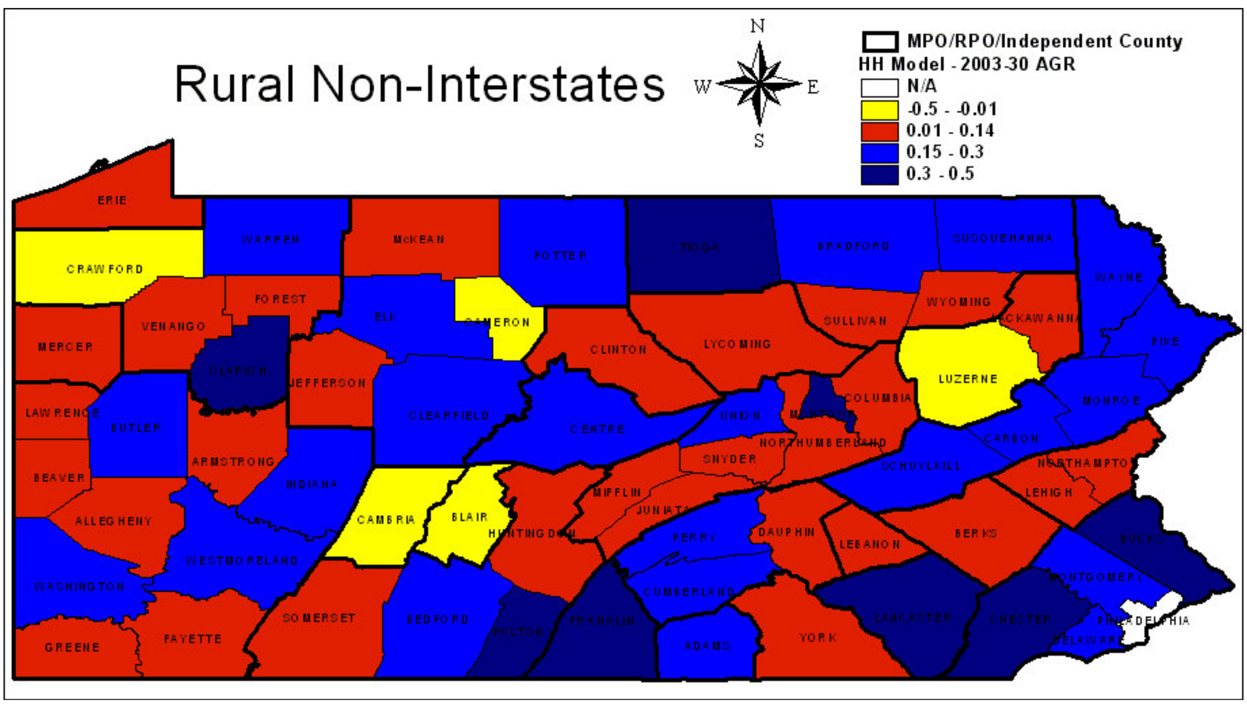


Figure 6-19. Rural Non-Interstate VMT 2003-2030 County Annual Growth Rates

6.5. Discussion

As noted in the previous section, the 2003 VMT re-classifications have dramatically shifted VMT among different categories. These VMT re-classifications were undertaken to account for changes in area types over the years, which happens during the urbanization process. It should be noted that the urbanization is a gradual process, and as a result, VMT shifts among urban and rural categories should also be a gradual process. However, VMT re-classification is undertaken only once every few years, in this case, ten years. Clearly, there is a mismatch between VMT data and socioeconomic variables, which change gradually.

One may wonder or even be concerned about the impacts of VMT reclassification on the regression estimations. It can be argued that these large shifts lead to a spurious correlation between VMT and lane miles. By definition, however, VMT is a function of lane miles and traffic volumes. Therefore, the relationship between VMT and lane mile is real. In economic sense, VMT reveals demand for travel, and lane miles represents supply. The degree to which the demand is elastic to supply is a subject of debate on induced travel. In the induced travel literature, the issue of reclassification impacts has received no attention. Re-classification does not affect the demand-supply relationship for the aggregate VMT, but may shift the relationships in individual facility categories. Therefore, the elasciticities, represented by the coefficients of lane mile per capita in this study, represent the combined effects of new supply and reclassifications, and cannot be interpreted as induced travel.

Various test runs were conducted to examine the impacts of re-classifications. First, the 2003 data were dropped, and models were re-estimated. For the household-based county-level regression models (MODEL HH), re-estimated coefficients for interstate categories are similar to the original estimates with the 2003 data. The differences in re-estimated coefficients reveal considerable impacts of re-classifications on the non-interstate categories. This does not mean that the 2003 data skew the model results and should be dropped. In fact, the models estimated without the 2003 data depict a relationship between VMT and independent variables under the condition of no classification, which is biased for the non-interstate categories. The 2003 data are a correction to this bias; the estimated models inclusive of the 2003 data represent a corrected relationship under the condition of reclassification. This corrected relationship is likely to hold in the future because the urbanization will continue and re-classification will be conducted in the future. It can be expected that the next re-classification will happen sometimes after the 2010 Census. It is possible that re-classification will take place in a shorter interval as the American Community Survey will replace the long form in 2010.

The second group of tests examines the explanatory powers of various independent variables including lane miles. As noted earlier, VMT is a function of lane miles and traffic volumes, and it is no surprise that VMT and lane miles are strongly correlated. Indeed, correlation coefficients are higher than 0.9 for all but the rural non-interstate category, which has a correlation coefficient of 0.81. When regressing VMT on lane miles alone, lane miles can explain more than 85 percent of the variance for facility categories, except for 66 percent for the rural non-interstate category. **Lane mile per capita** is used in the models that are presented in the earlier sections. The correlations between VMT and lane miles per capita are much weaker than those between

VMT and lane miles. When regressing VMT on **lane miles per capita** alone, lane miles per capita can only explain from 1 to 53 percent of the variance. This is a clear indication that **lane miles per capita** are not a variable that dominates the estimated models. Indirectly, this shows that reclassification does not overwhelm the models, although having some impacts on the model results. Adding socioeconomic variables in the regressions increases the explanatory power to higher than 90 percent, except for 84 percent for the rural non-interstate category. Clearly, socioeconomic variables and lane mile per capita together have substantial explanatory power for the VMT variations. It is also an indication that the dummy variables added to the regressions do not dominate the estimated models.

A series of sensitivity tests was also conducted to examine the effects of lane mile growth assumptions on the future VMT growth. Lane miles were assumed to grow the same rates as those in the 1994-2003 period and alternatively, half those rates. Table 6-13 shows forecasted VMT annual growth rates from the county-level household-based models, based on different assumptions about lane mile changes in the future. Table 6-14 shows the same type of results from the county-group-level household-based models. As can be seen in these two tables, the models show some degree of sensitivity to the lane mile assumption in the future. It should be noted that lane miles will be not likely, if not impossible, to change in the 2003-2030 period with the same growth rates as those in the 1994-2003. Therefore, the last sensitivity testing results in these two tables are only shown for the illustration purpose.

Table 6-13. LM Sensitivity Tests of Model HH (VMT Annual Growth Rates)

Model (Forecasting Assumption for LM)	Facility	1994-03	2003-10	2010-20	2020-30
Model HH (Asumming Constant LM for the Future)	Rural Interstates	4.09%	3.72%	3.40%	2.95%
	Rural Non-Interstates	-0.87%	0.48%	0.24%	-0.13%
	Urban Interstates	4.12%	3.03%	2.88%	2.62%
	Urban Non-Interstates	1.73%	1.41%	1.07%	0.57%
	Total	1.54%	1.74%	1.58%	1.31%
Model HH (Asumming LM Grows as Half Rates of 1994-2003)	Rural Interstates	4.09%	3.90%	3.58%	3.12%
	Rural Non-Interstates	-0.87%	0.23%	-0.02%	-0.39%
	Urban Interstates	4.12%	3.54%	3.39%	3.14%
	Urban Non-Interstates	1.73%	1.50%	1.16%	0.65%
	Total	1.54%	1.84%	1.72%	1.52%
Model HH (Asumming LM Grows as 1994-2003)	Rural Interstates	4.09%	4.07%	3.75%	3.30%
	Rural Non-Interstates	-0.87%	-0.03%	-0.28%	-0.64%
	Urban Interstates	4.12%	4.06%	3.90%	3.65%
	Urban Non-Interstates	1.73%	1.58%	1.25%	0.74%
	Total	1.54%	1.95%	1.89%	1.75%

Table 6-14. LM Sensitivity Tests of Model CntyGrp HH (VMT Annual Growth Rates)

Model (Forecasting Assumption for LM)	Facility	1994-03	2003-10	2010-20	2020-30
Model CntyGrp HH (Asumming Constant LM for the Future)	Rural Interstates	4.09%	2.11%	2.15%	2.10%
	Rural Non-Interstates	-0.87%	0.91%	0.09%	-1.09%
	Urban Interstates	4.12%	1.39%	1.31%	1.12%
	Urban Non-Interstates	1.73%	0.76%	0.42%	-0.13%
	Total	1.54%	1.07%	0.72%	0.23%
Model CntyGrp HH (Asumming LM Grows as Half Rates of 1994-2003)	Rural Interstates	4.09%	2.28%	2.33%	2.28%
	Rural Non-Interstates	-0.87%	0.24%	-0.57%	-1.74%
	Urban Interstates	4.12%	2.25%	2.16%	1.97%
	Urban Non-Interstates	1.73%	0.97%	0.62%	0.08%
	Total	1.54%	1.17%	0.88%	0.50%
Model CntyGrp HH (Asumming LM Grows as 1994-2003)	Rural Interstates	4.09%	2.45%	2.50%	2.46%
	Rural Non-Interstates	-0.87%	-0.43%	-1.23%	-2.40%
	Urban Interstates	4.12%	3.11%	3.02%	2.83%
	Urban Non-Interstates	1.73%	1.17%	0.83%	0.29%
	Total	1.54%	1.29%	1.10%	0.87%

7. Conclusions and Recommendations

The ultimate objective of this study is to identify a preferred traffic growth forecasting method for implementation. To achieve this objective, the results of all above tasks and subtasks were synthesized and finalist methods were evaluated in terms of PENNDOT needs. We also briefed the PENNDOT project team, explaining the study and evaluation undertaken, findings, results and preliminary conclusions. As a result, consensus was developed on the preferred traffic forecasting method for implementation.

In summary, major conclusions and recommendations are as follows:

- Regression models best meet PENNDOT needs for a statewide VMT growth forecasting system. In particular, regression-based forecasting models provide a consistent statewide forecasting framework.

- Data needed for implementing a regression-based forecasting system are readily available, updated annually, and reasonably priced. The PENNDOT database maintained by Bureau of Research and Planning provides an excellent source for VMT, lane miles, and other key variables. State profile database for Pennsylvania, produced by Woods & Poole Economics, is recommended as the data source for socioeconomics.

- It is recommended that PENNDOT forecast VMT growth as a range and averaged middle point (see Figures 7-1, 2 and 3 and Table 7-1), as follows:

  a. The upper boundary of the VMT forecasts (all facility classes) is based on the household-based county-level regression models (MODEL HH). This model produces the most consistent and logical forecasts among candidate models.

  b. The lower boundary of the VMT forecast (for interstate facility classes) is based on the household-based county-group-level regression models.

  c. The "middle point estimate" of forecast VMT is created by averaging the upper and lower boundaries of forecasts from the two models at the state level, and then adjusting the forecasts from MODEL HH at the county level so as to match the averaged forecasts at the state level.

- The regression models should be updated annually, based on new VMT and socioeconomic data. The VMT forecasting system is summarized in Figure 7-4. A spreadsheet file is created as a prototype for the forecasting system implementation (see Appendix E for a brief description and the spreadsheet for the details).

- Potential future investigation includes evaluation of air quality implications of the recommended VMT forecasting system, improved lane mile data for future years, and incorporation of intra-county level socioeconomic and land use variables in the forecasting system. Socioeconomic and land use data at the sub-county level such as township will provide more fine-grained picture than those at the county level and may improve the VMT growth forecasting.

Table 7-1. Annual Growth Rates (Averaged for Interstates)

Model	Facility Category	1994-03	2003-10	2010-20	2020-30
Averaged Rates for Interstates (HH+CntyGrp HH)	Rural Interstates	4.09%	2.93%	2.83%	2.58%
	Rural Non-Interstates	-0.87%	0.48%	0.24%	-0.13%
	Urban Interstates	4.12%	2.23%	2.16%	2.00%
	Urban Non-Interstates	1.73%	1.41%	1.07%	0.57%
	Total	1.54%	1.49%	1.31%	1.03%

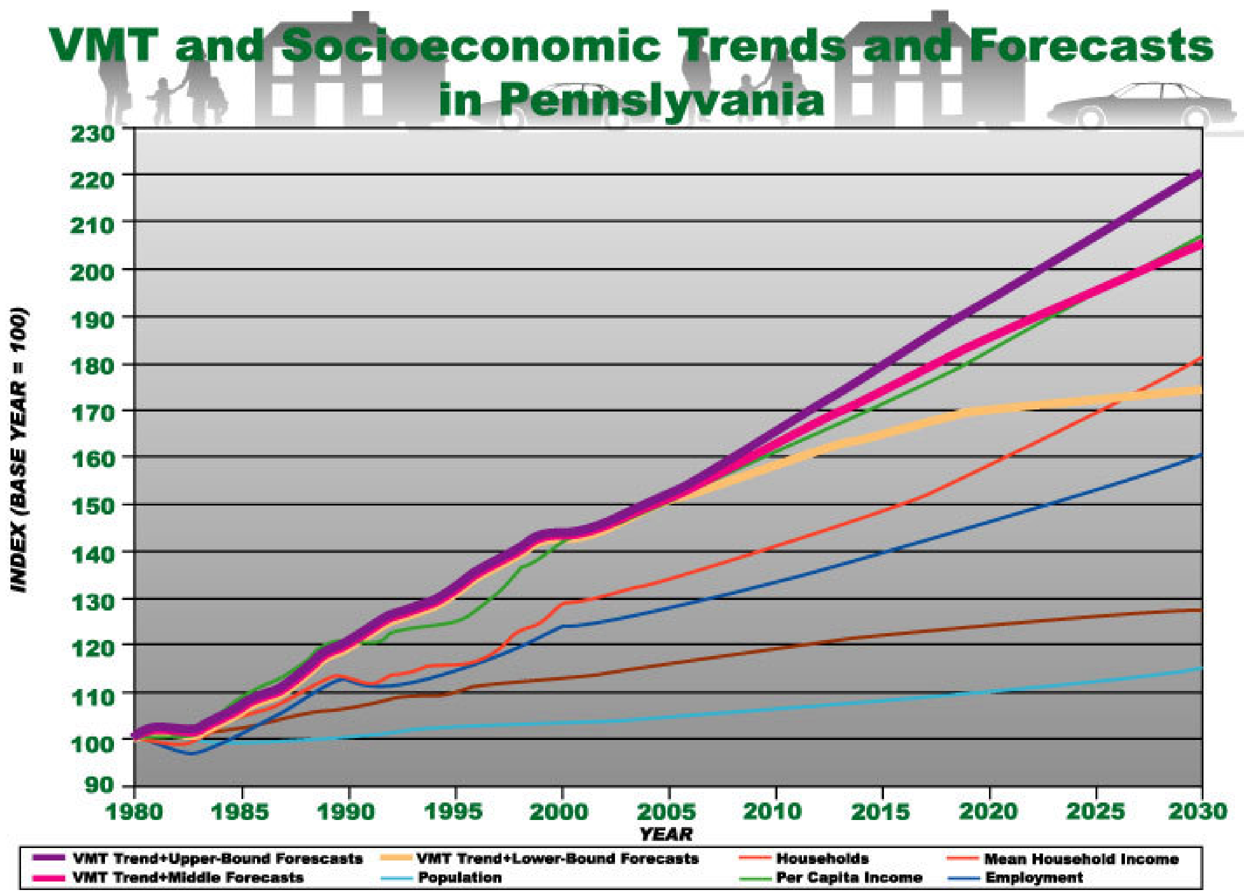


Figure 7-1. Statewide VMT and Socioeconomic Growth Trend and Forecasts

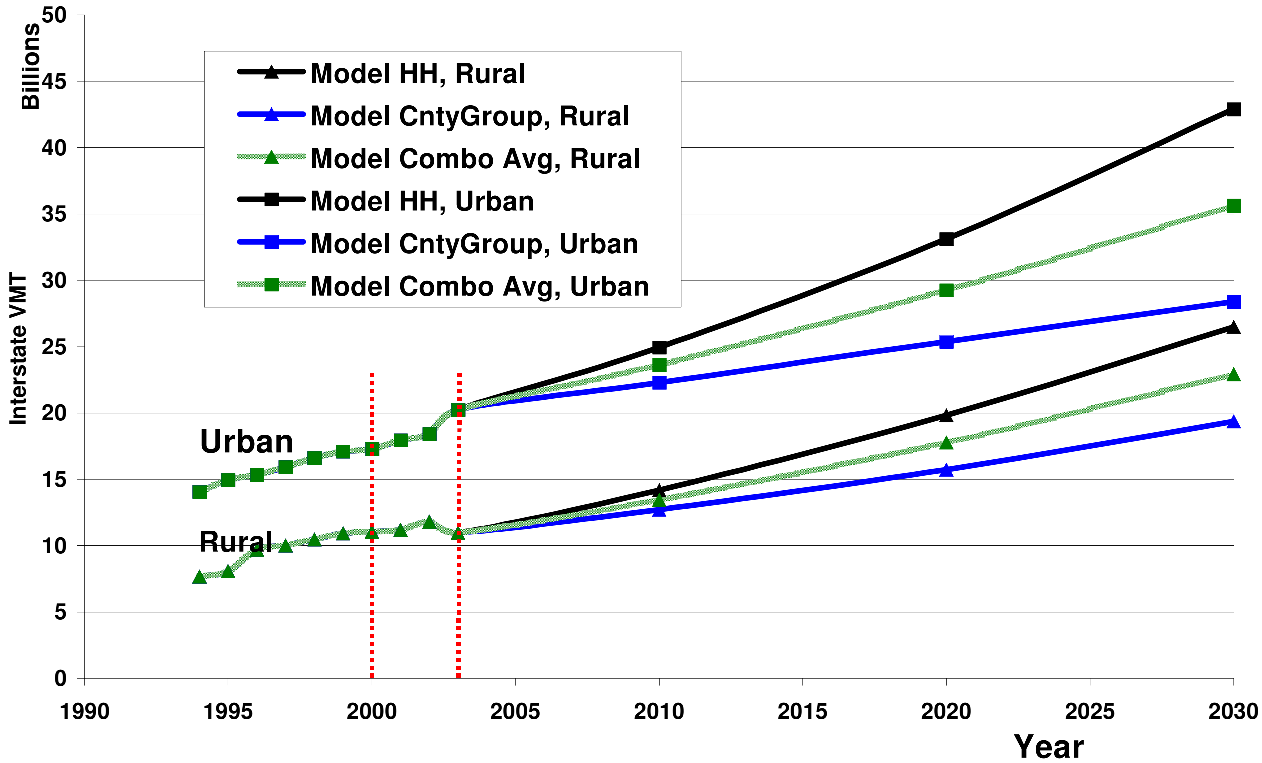


Figure 7-2. Recommended VMT Growth Forecasting Scenarios for Interstates

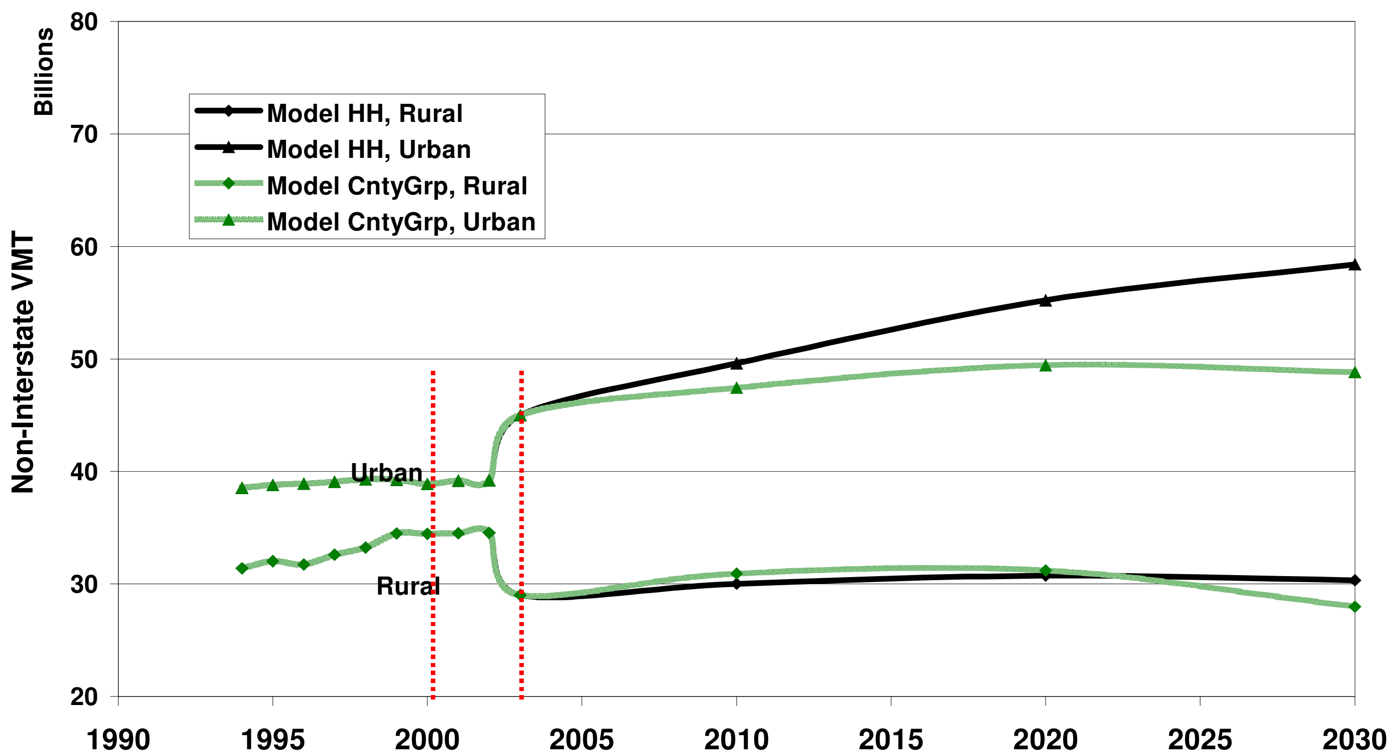


Figure 7-3. Recommended VMT Growth Forecasting Scenarios for Non-Interstates

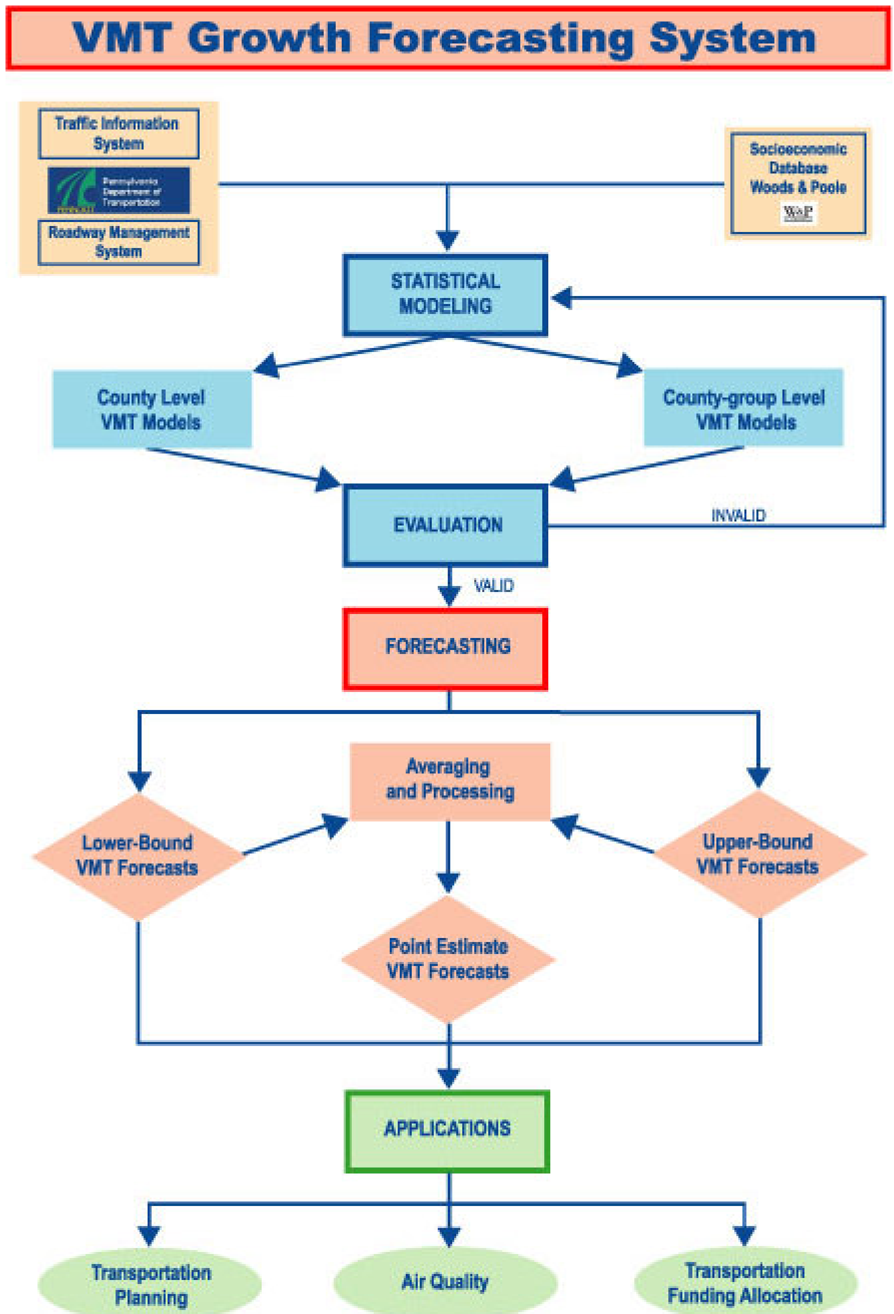


Figure 7-4. VMT Growth Forecasting System

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Appendix A. VMT and LM Growth Trend by County

1994-2002

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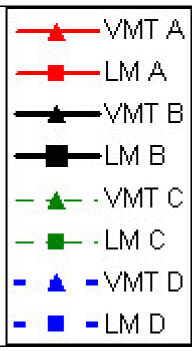
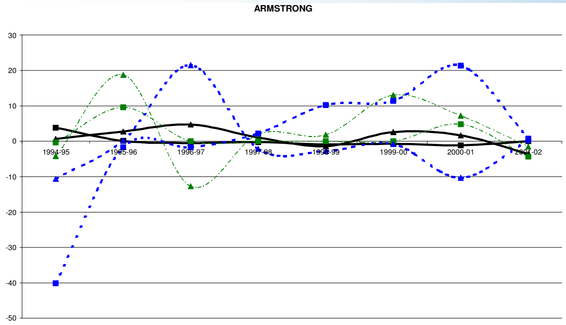


VMT A: Rural Interstates Vehicle Miles Traveled
LM A: Rural Interstates Lane Miles
VMT B: Rural Non-Interstates Vehicle Miles Traveled
LM B: Rural Non-Interstates Lane Miles
VMT C: Urban Interstates Vehicle Miles Traveled
LM C: Urban Interstates Lane Miles
VMT D: Urban Non-Interstates Vehicle Miles Traveled
LM D: Rural Non-Interstates Lane Miles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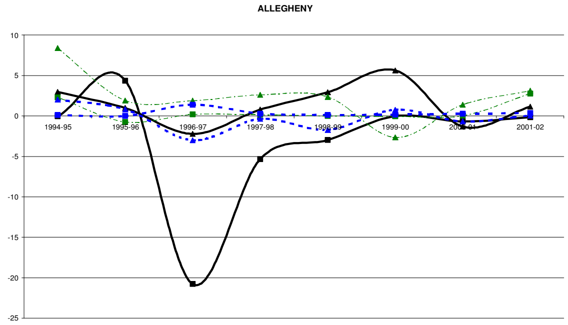
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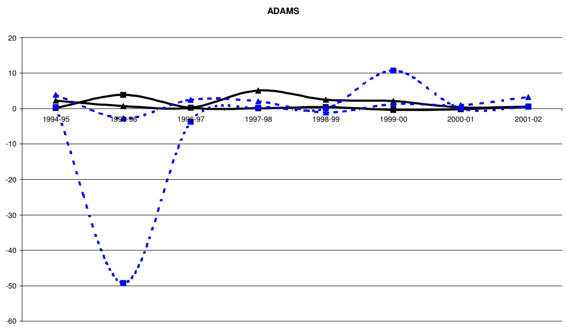
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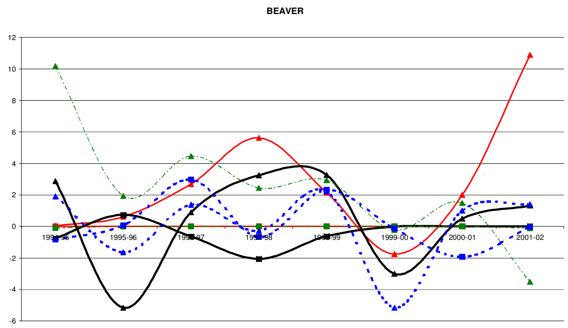
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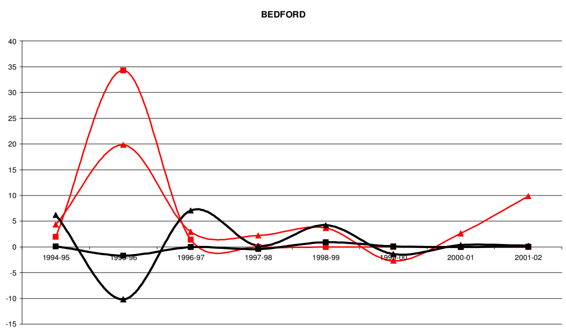
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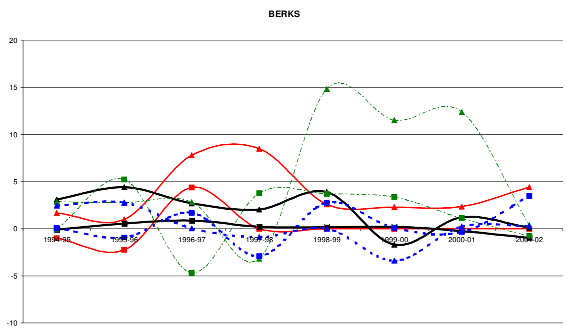
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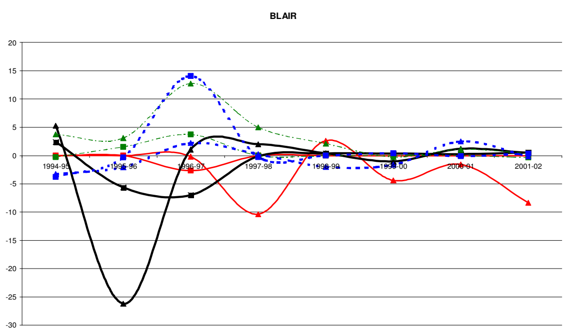
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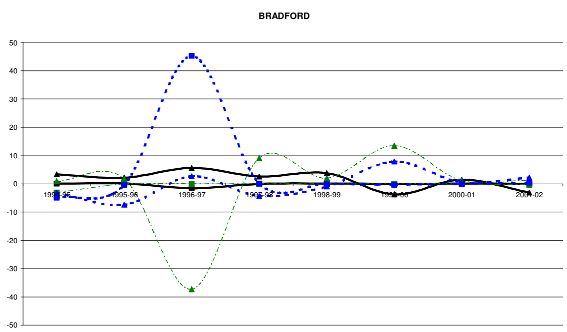
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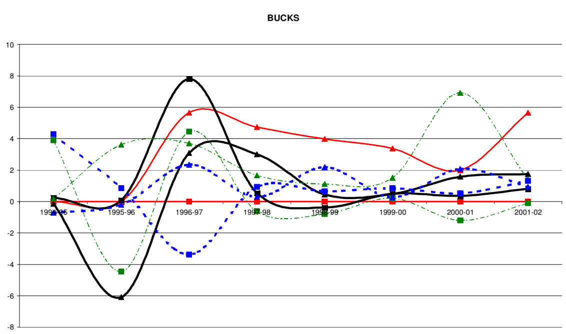
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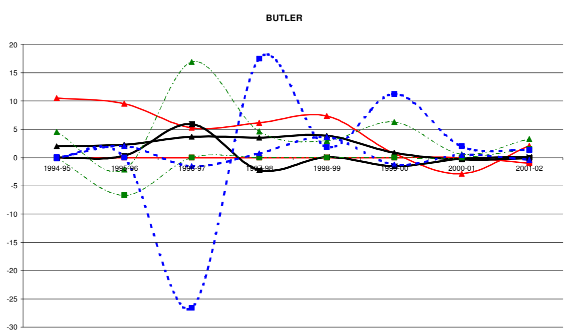
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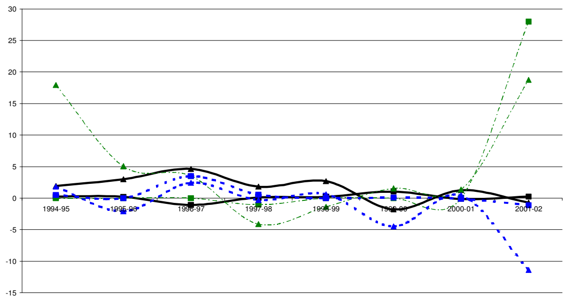

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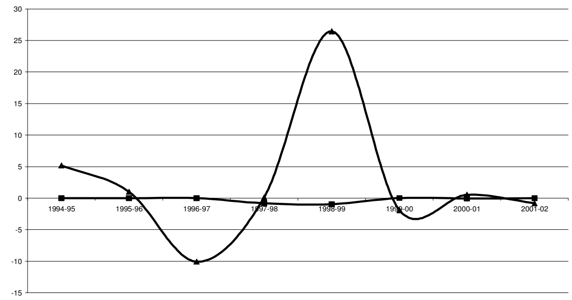

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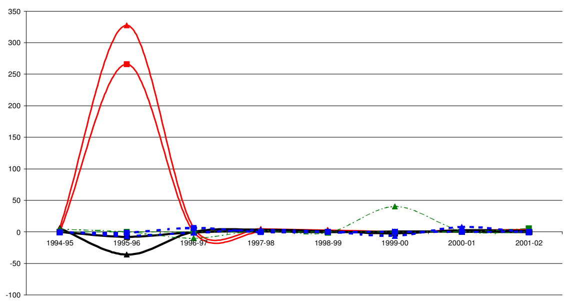

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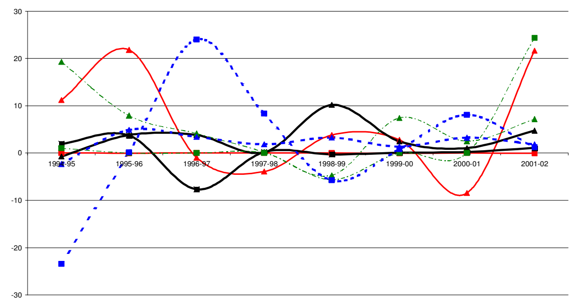

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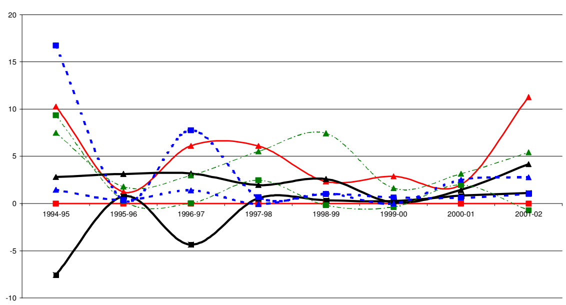

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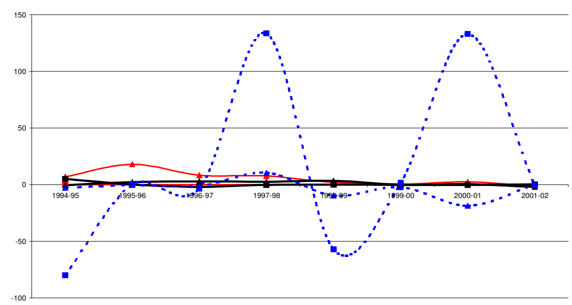

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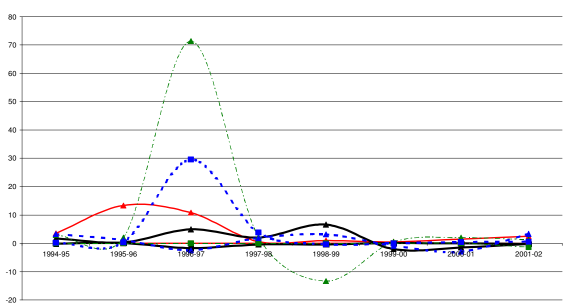

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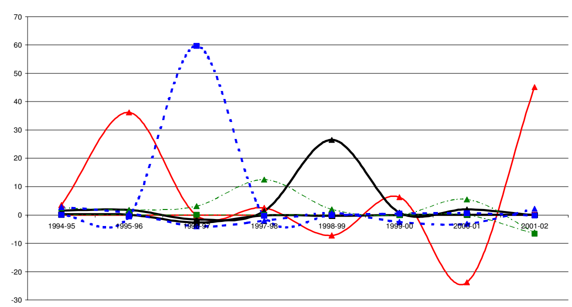

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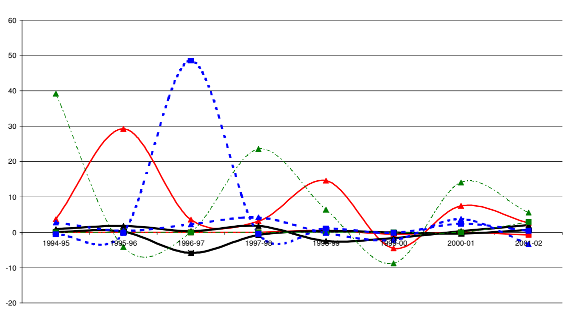

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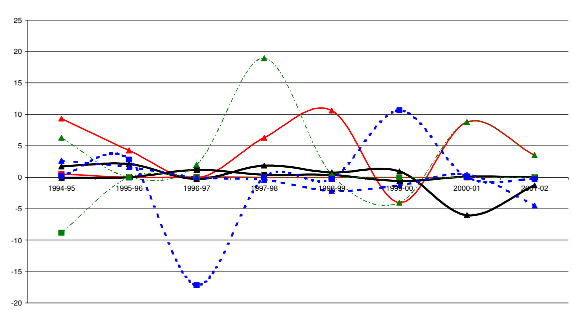

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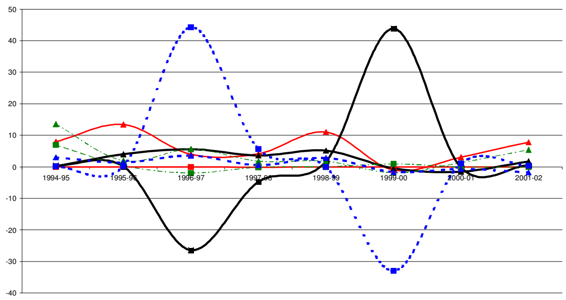

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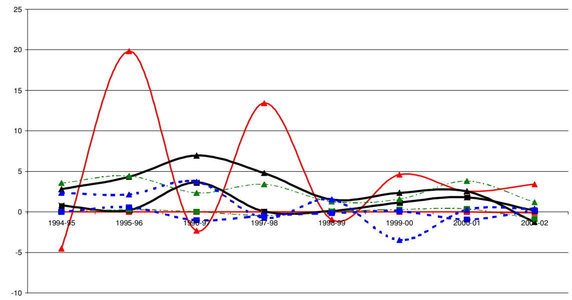

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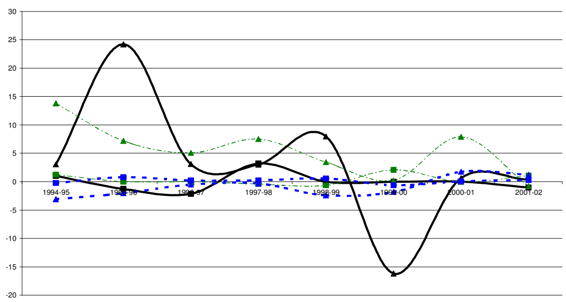

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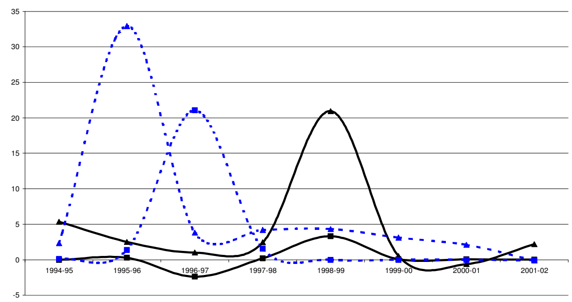

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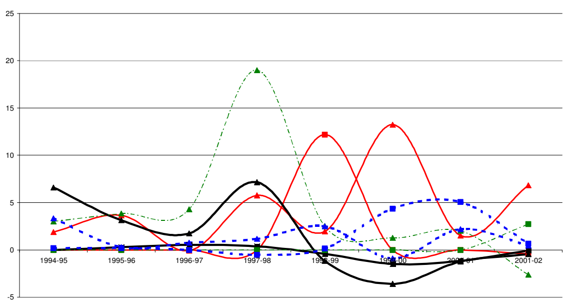

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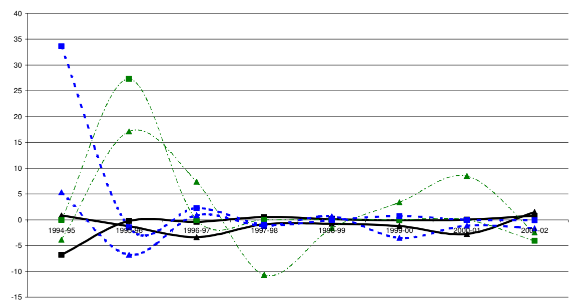

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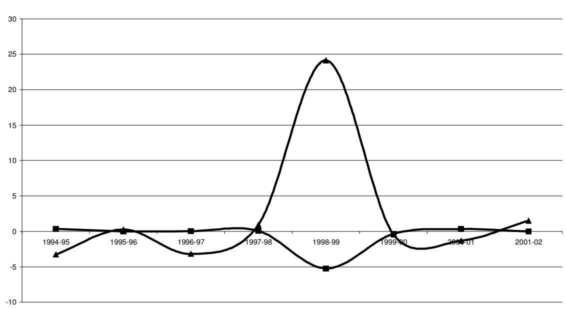

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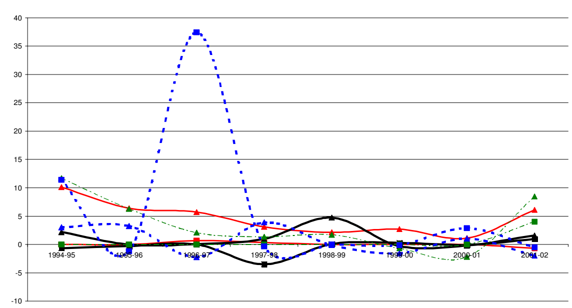

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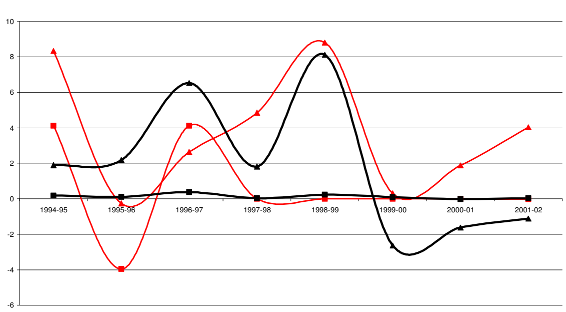

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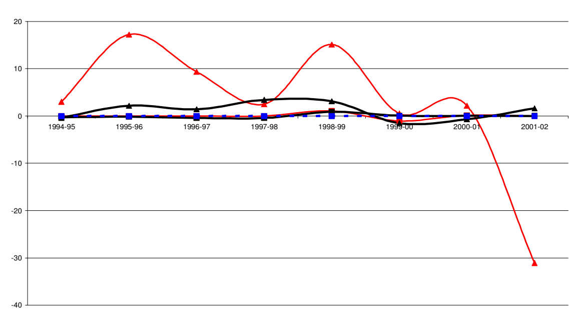

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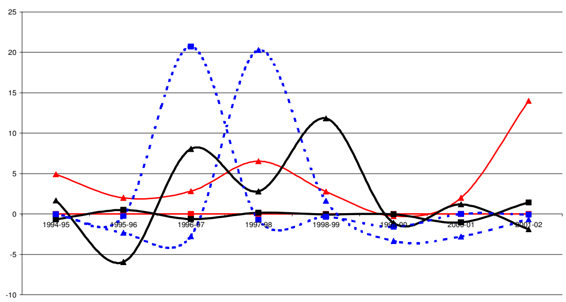

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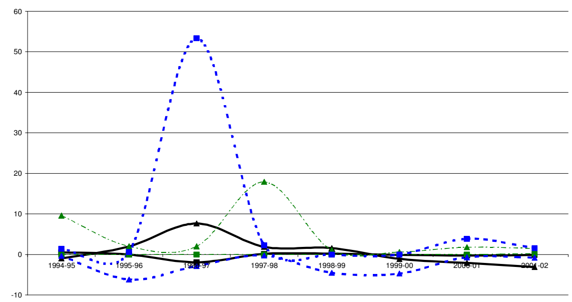

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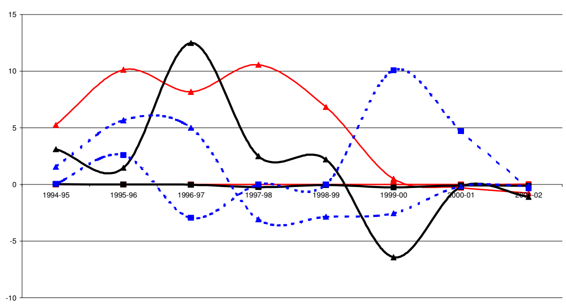

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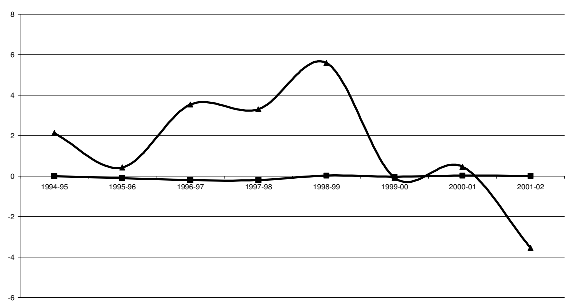

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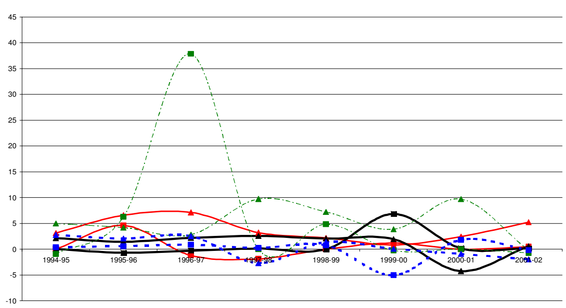

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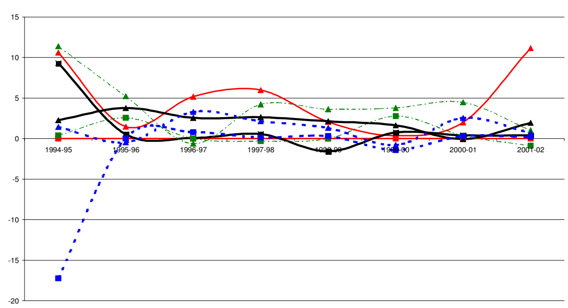

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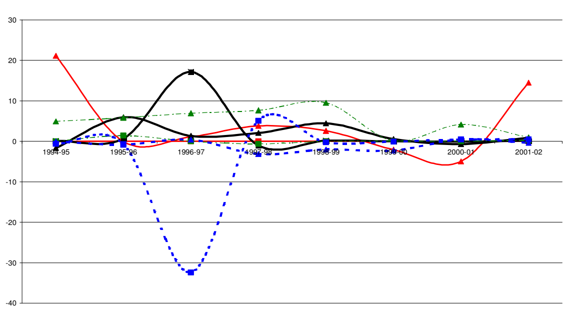

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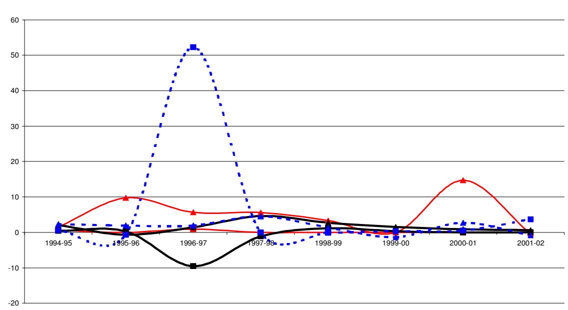

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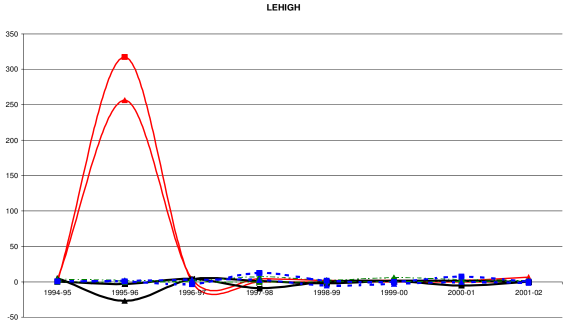

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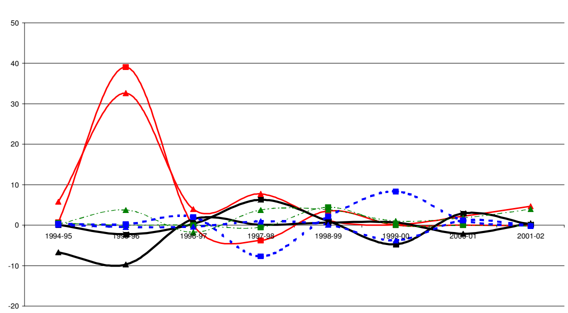

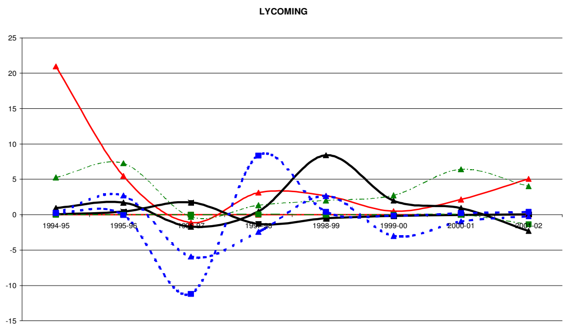
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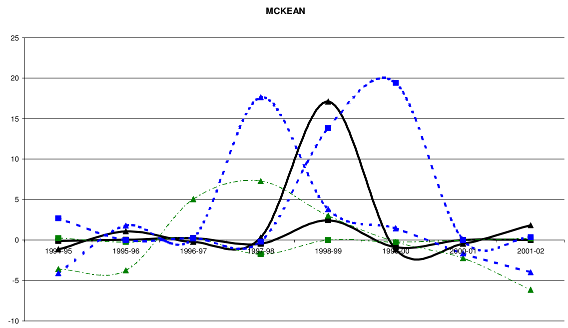
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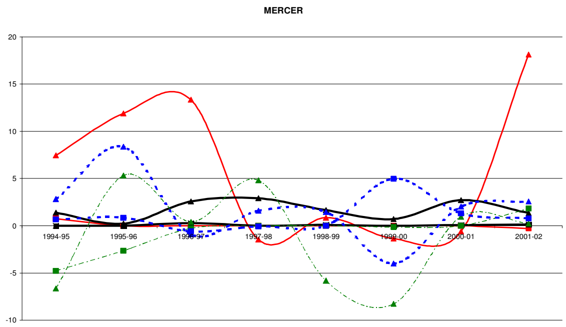
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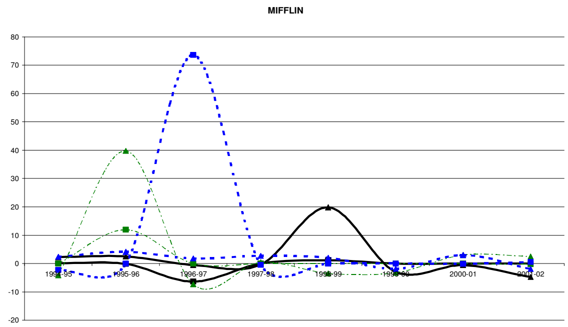
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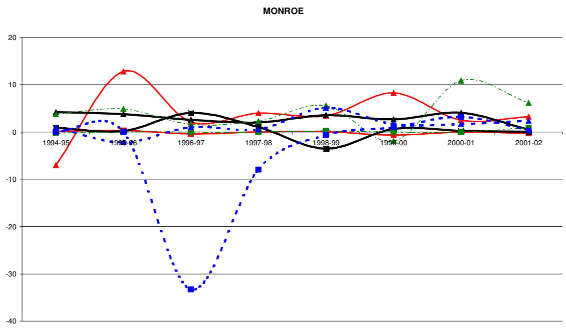
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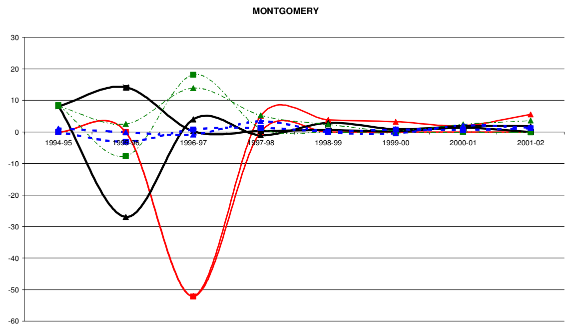
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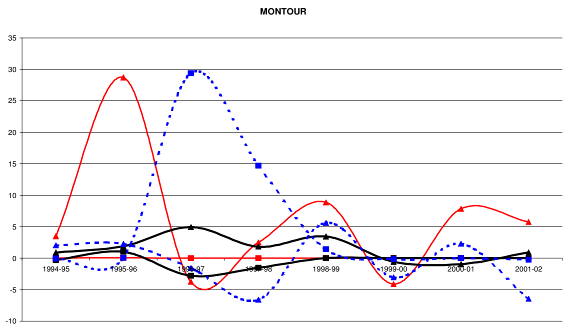
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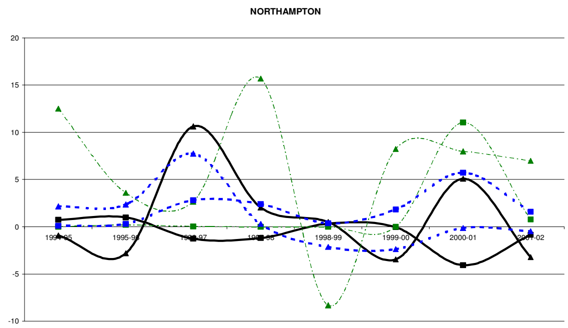
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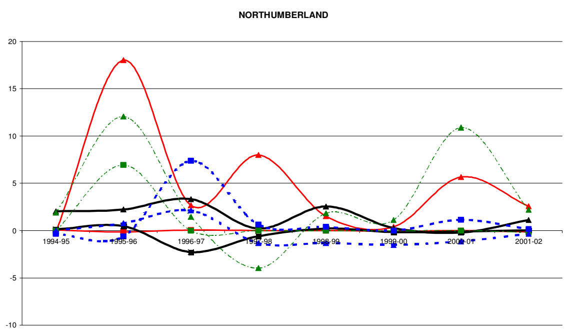
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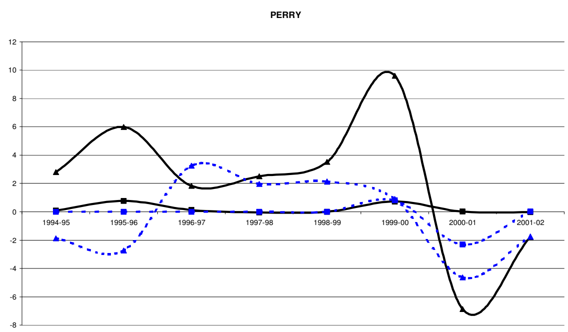
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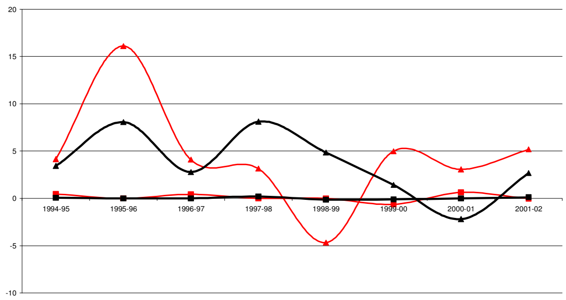

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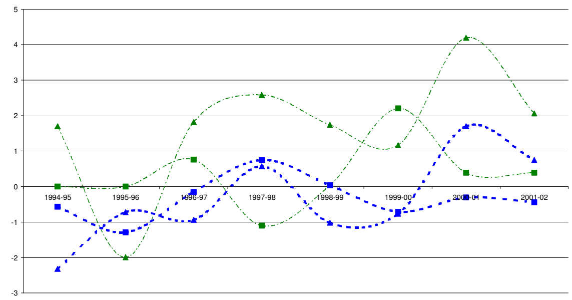

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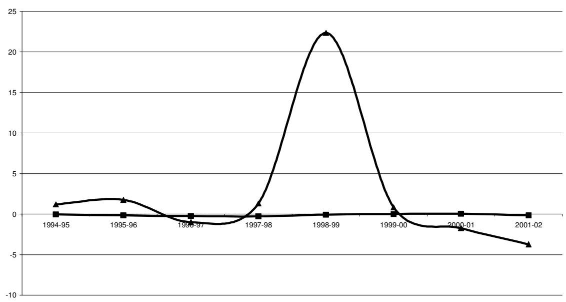

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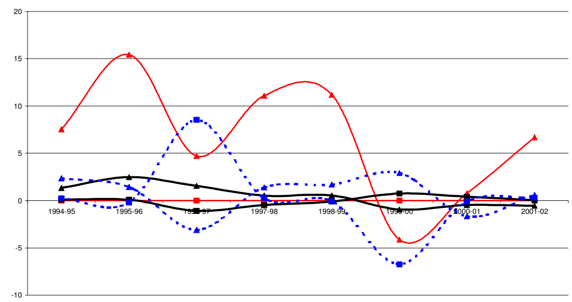

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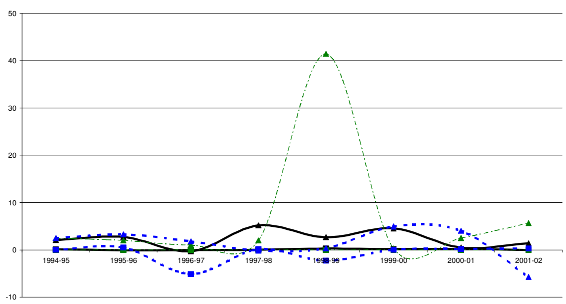

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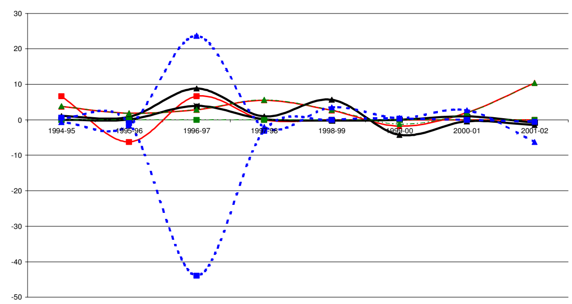

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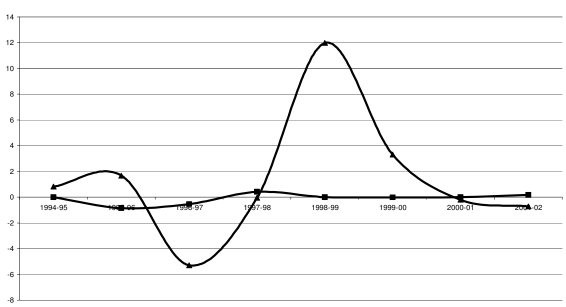

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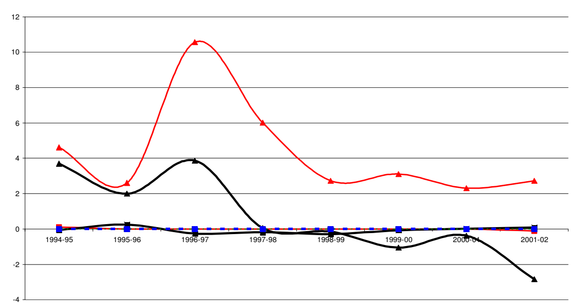

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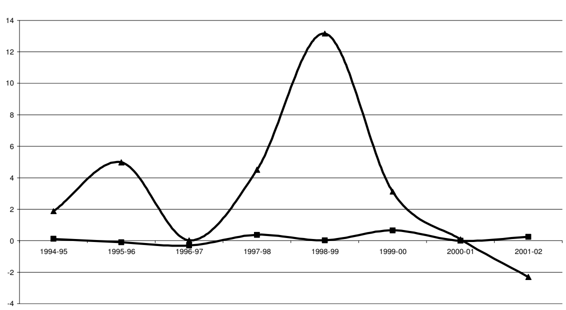

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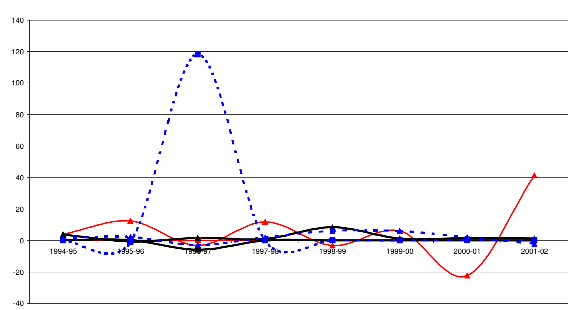

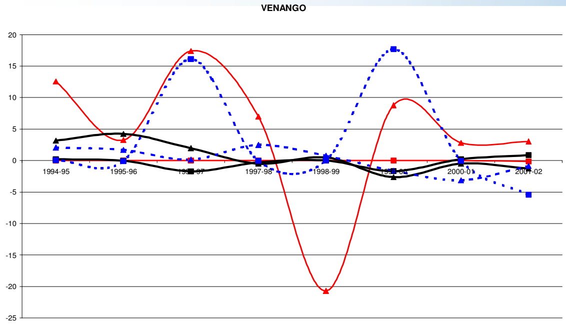
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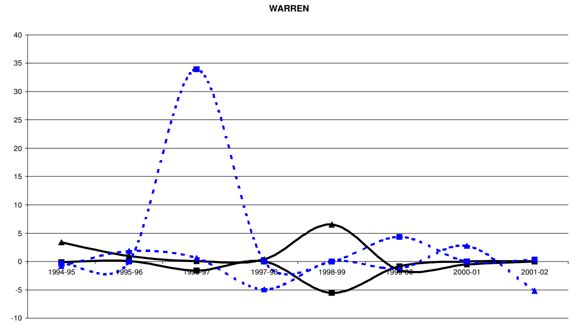
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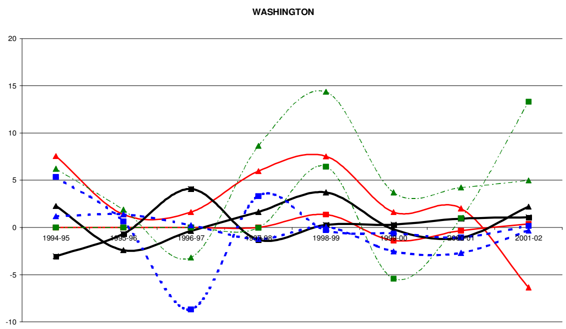
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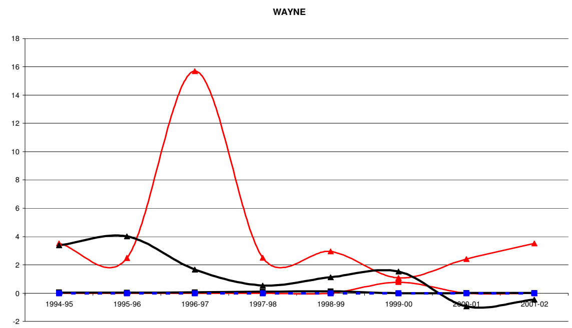
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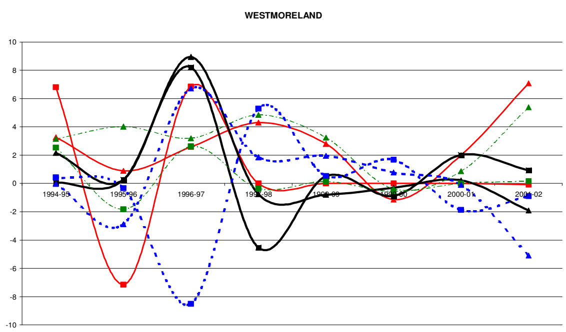
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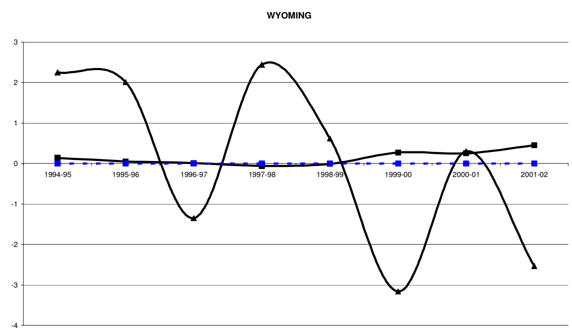
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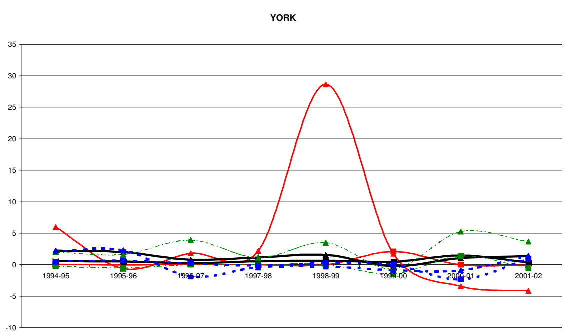
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Appendix B. Socioeconomic Growth Trend by County

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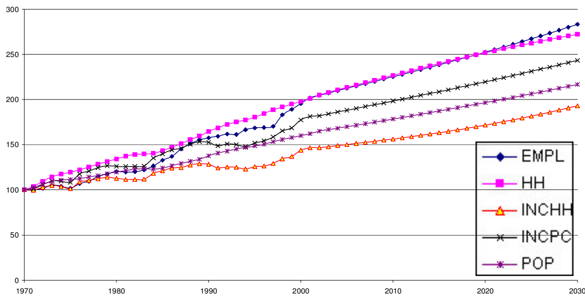

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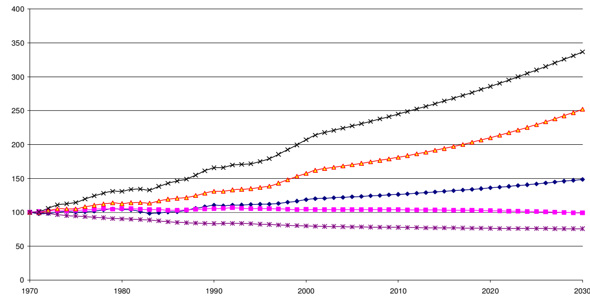

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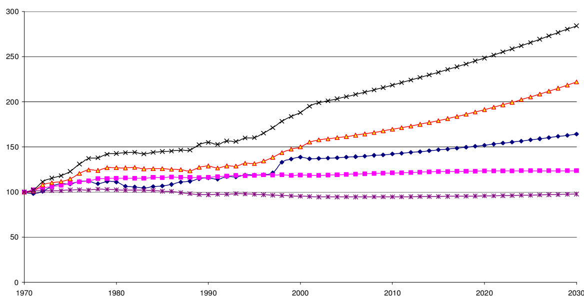

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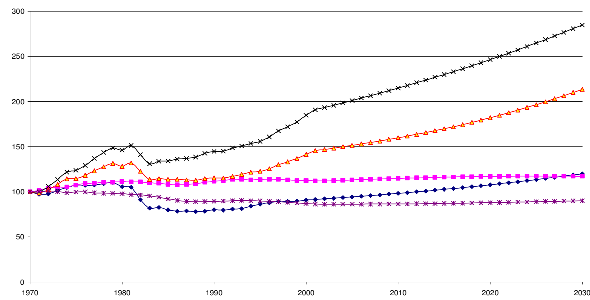

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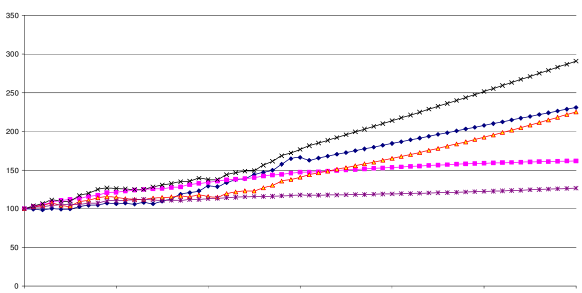

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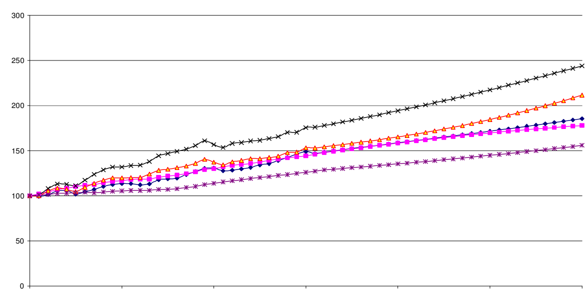

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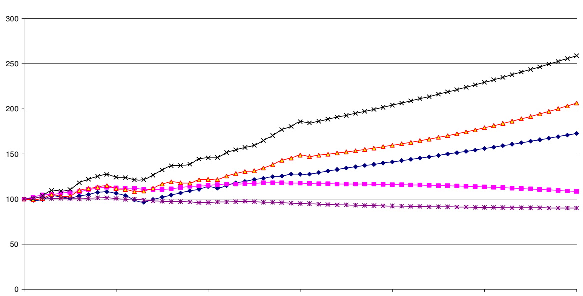

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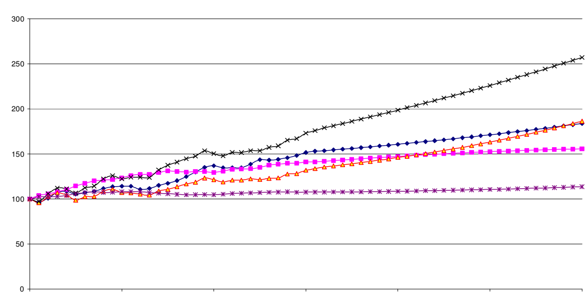

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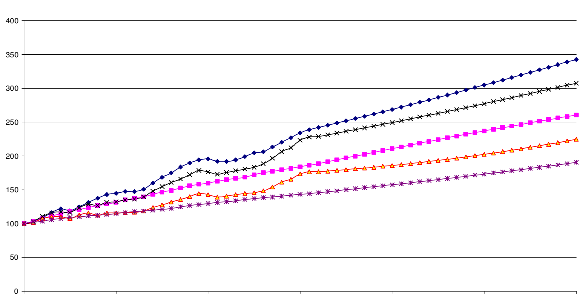

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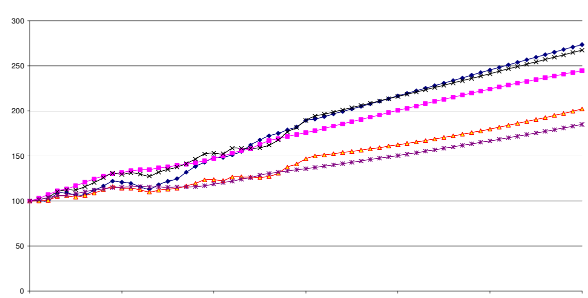

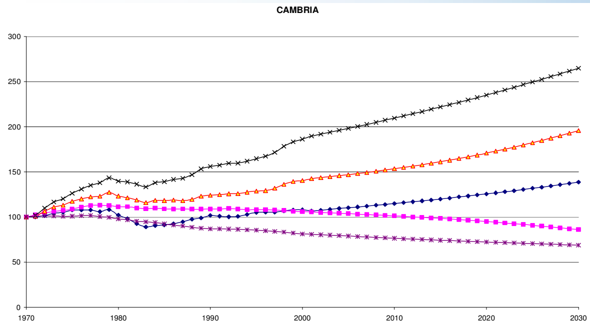
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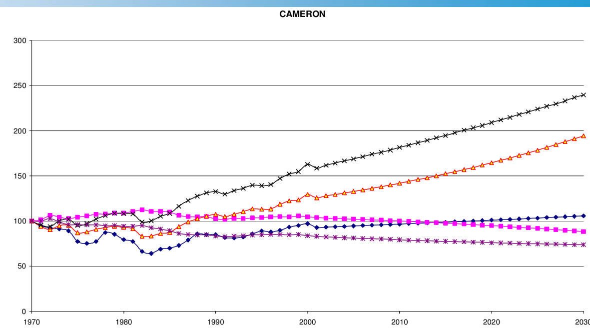
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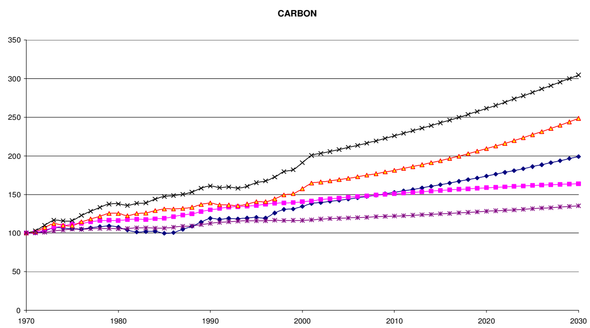
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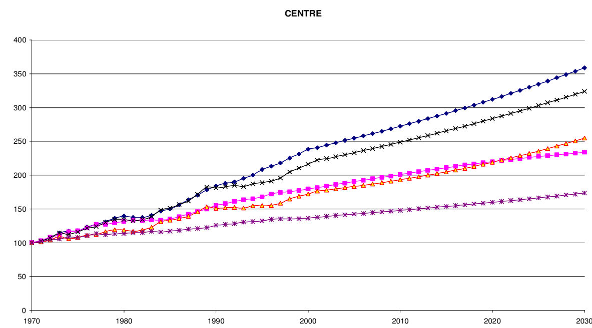
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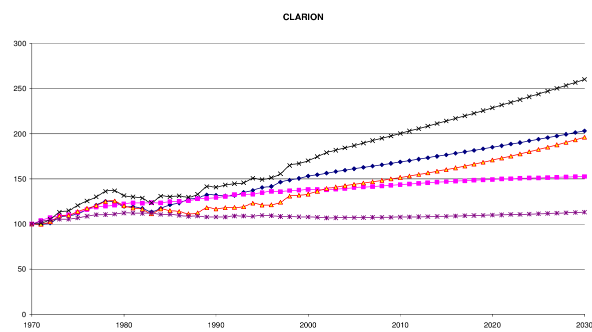
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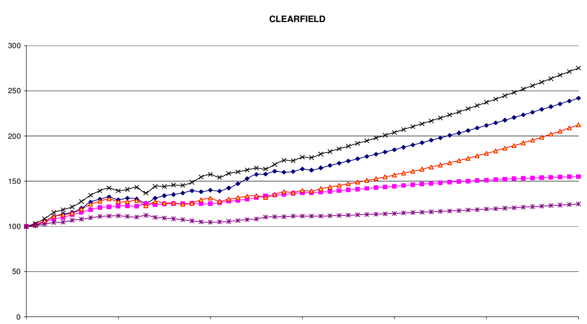
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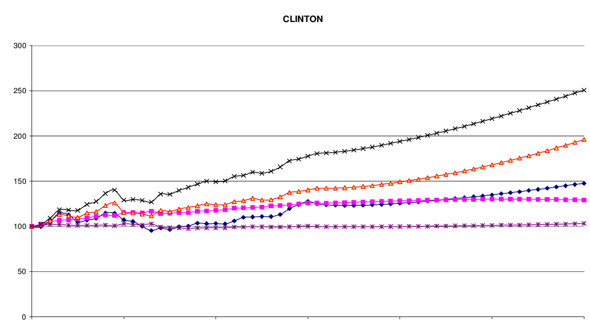
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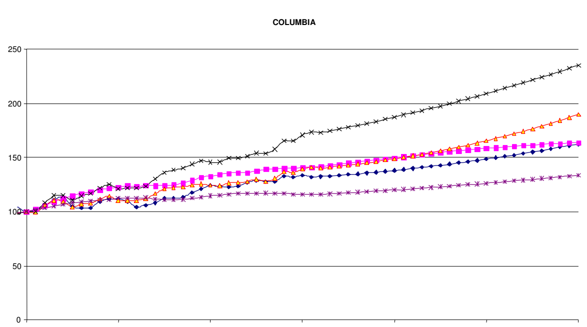
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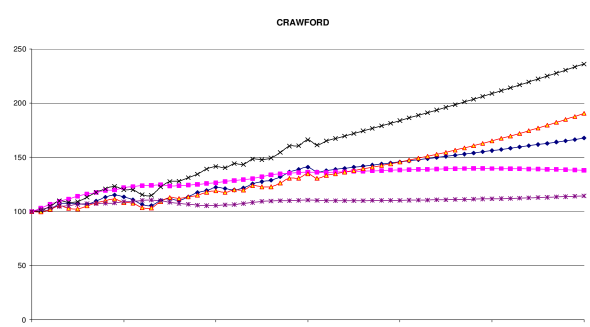
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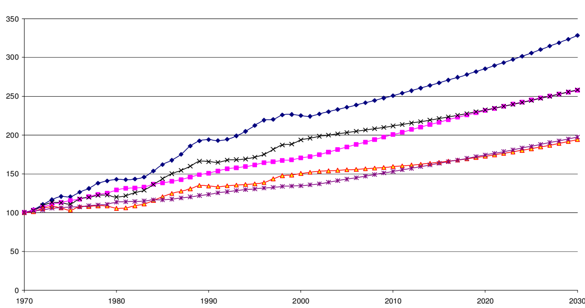

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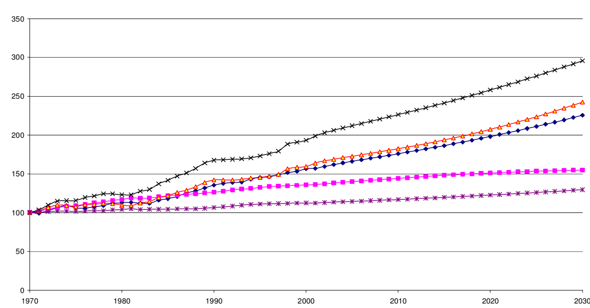

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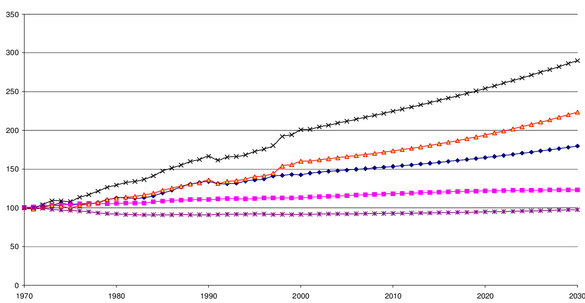

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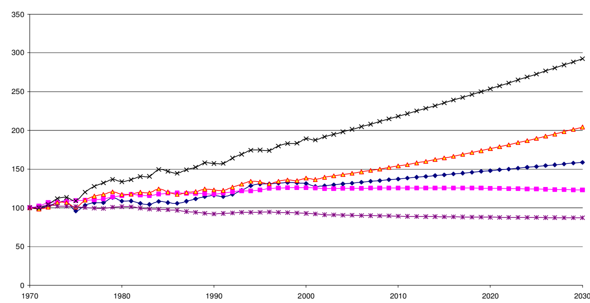

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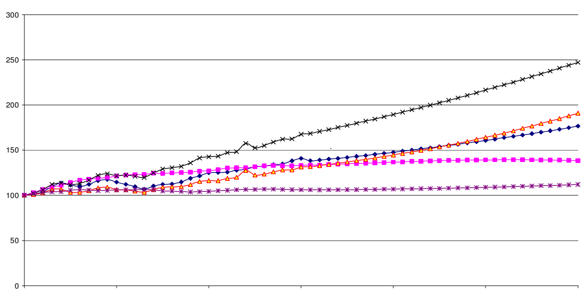

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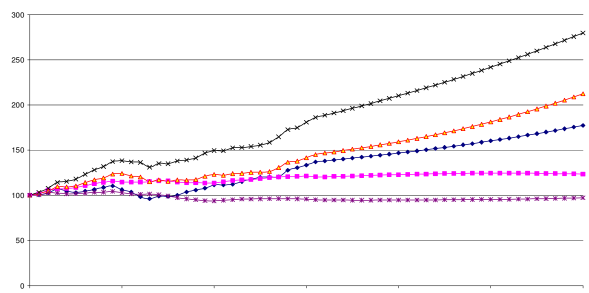

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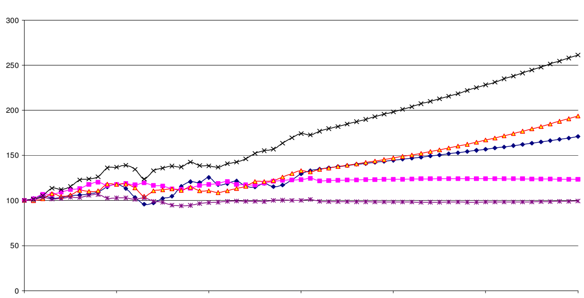

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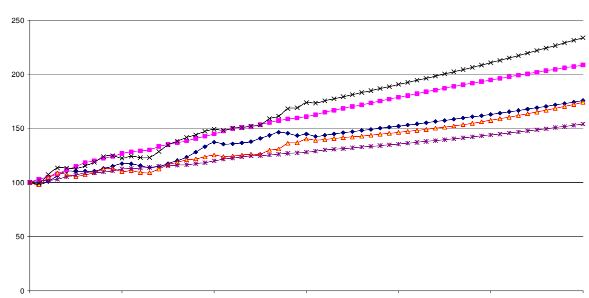

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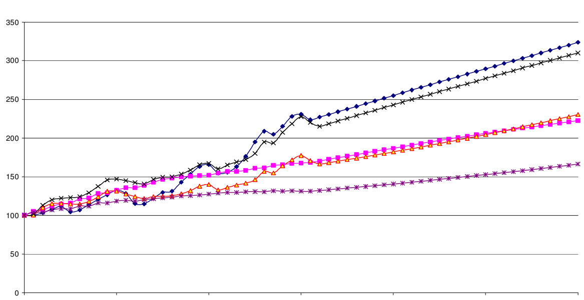

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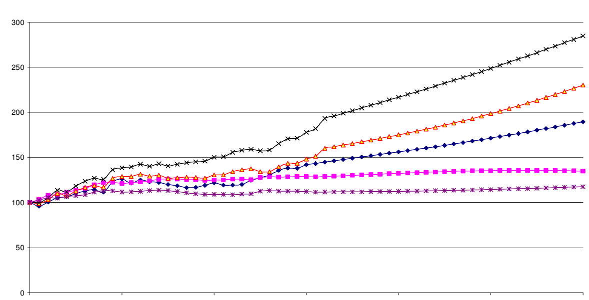

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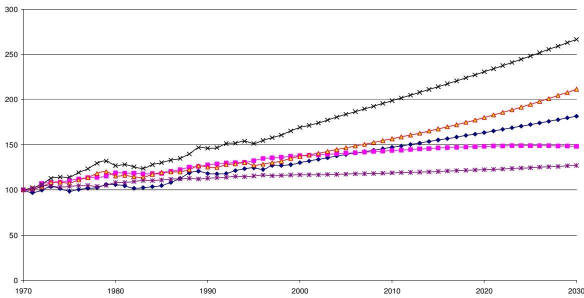

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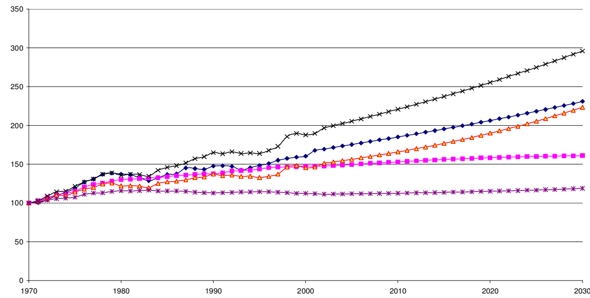

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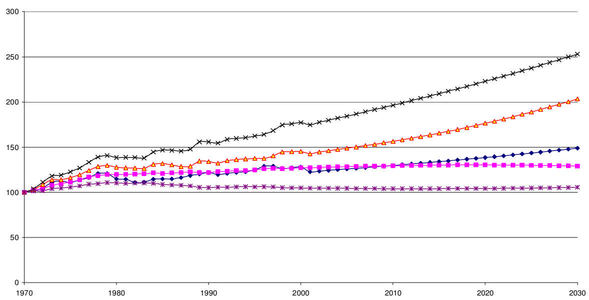

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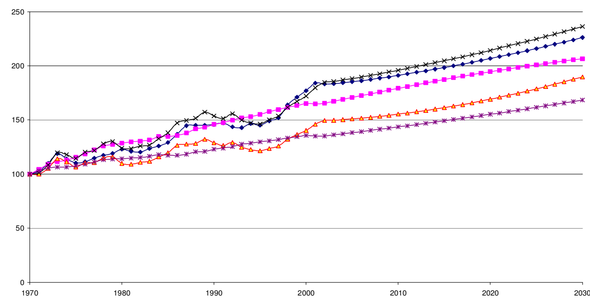

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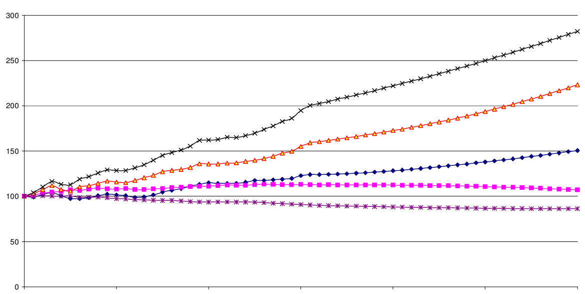

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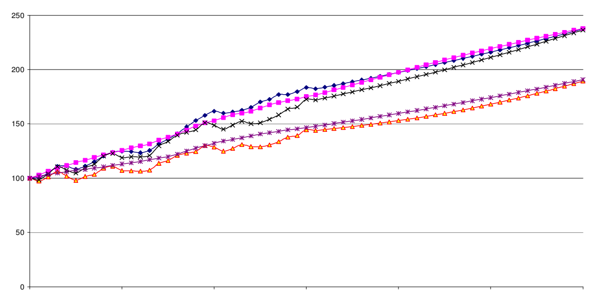

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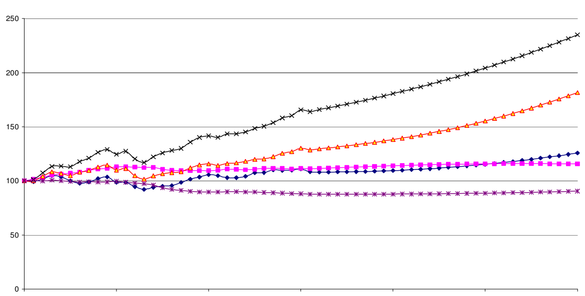

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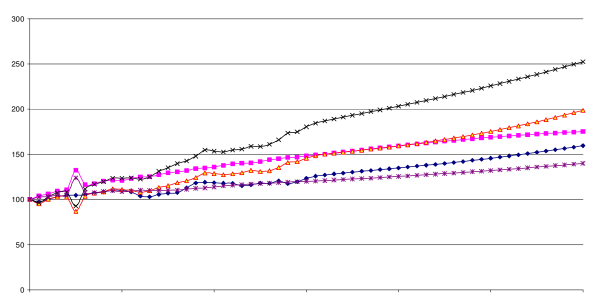

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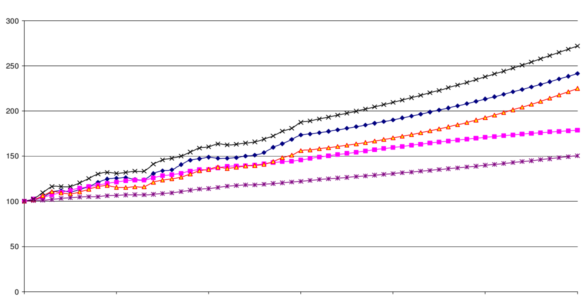

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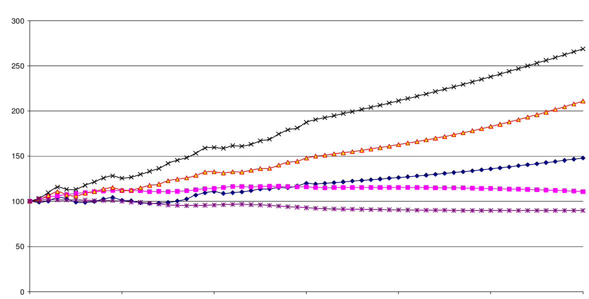

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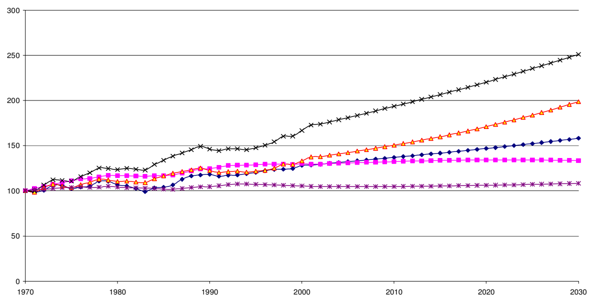

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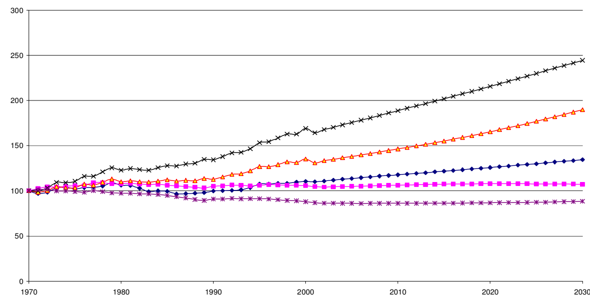

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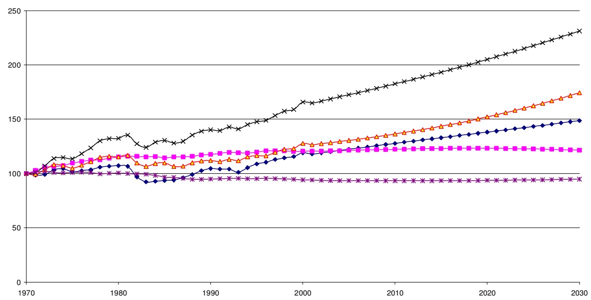

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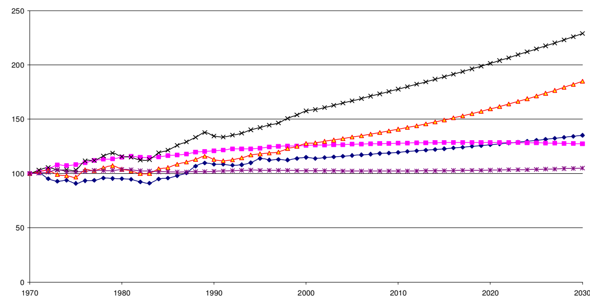

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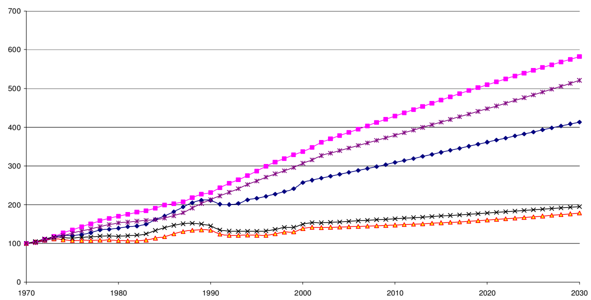

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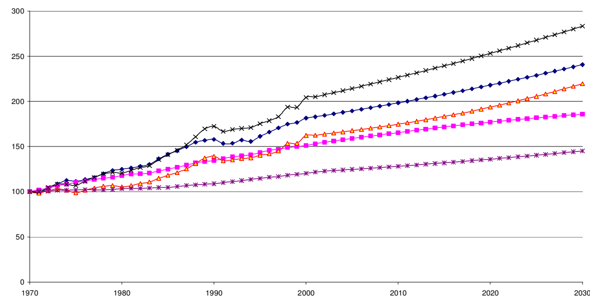

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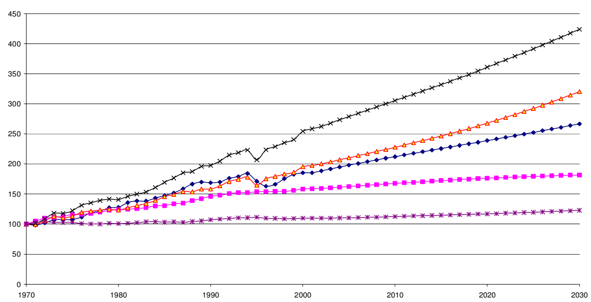

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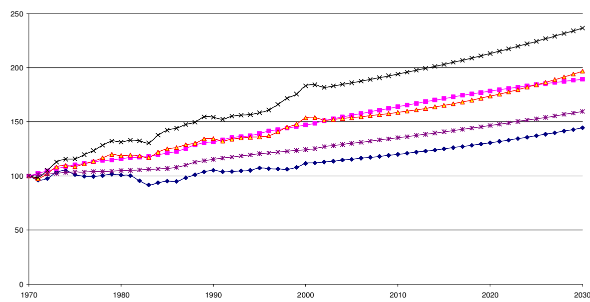

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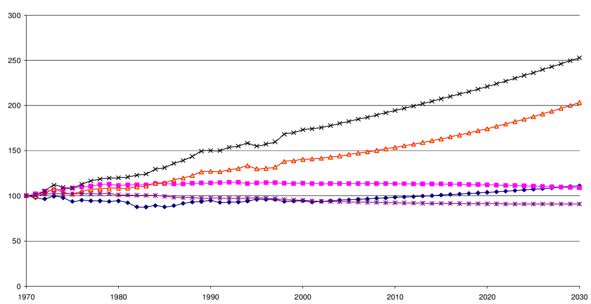

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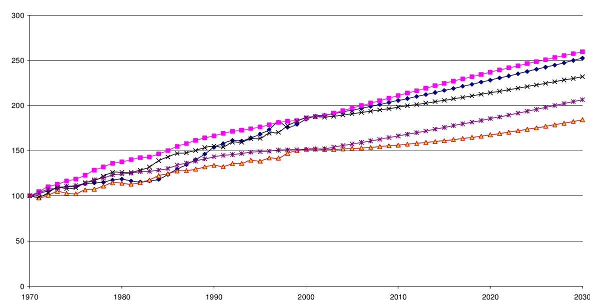

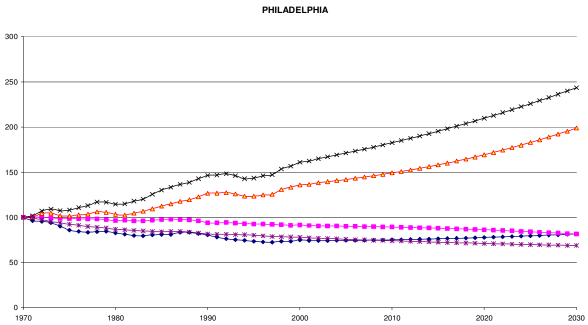
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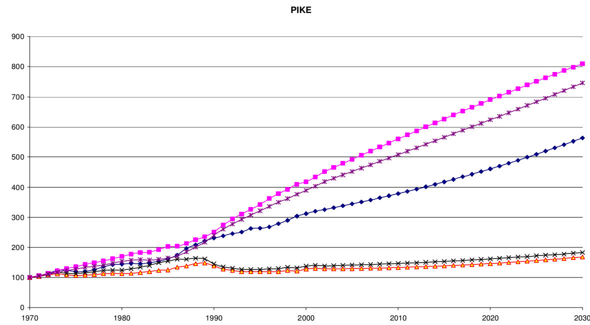
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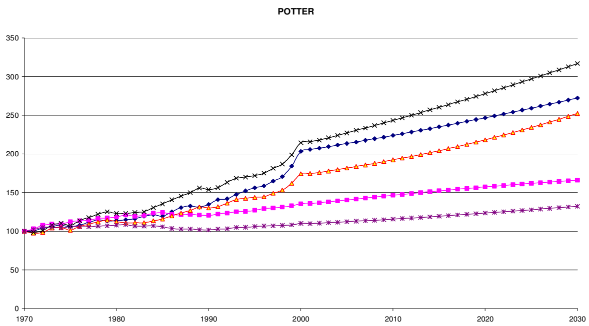
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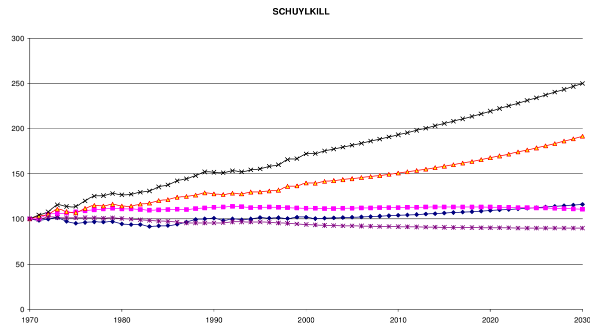
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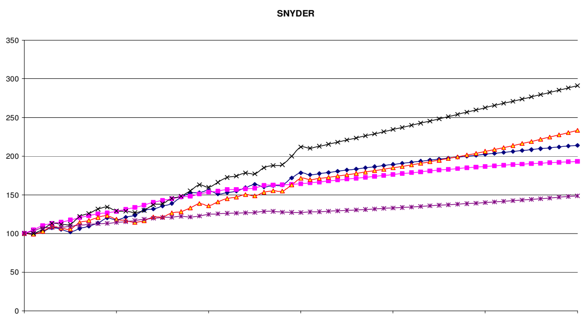
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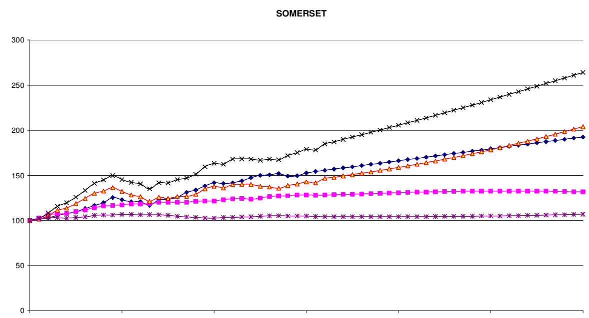
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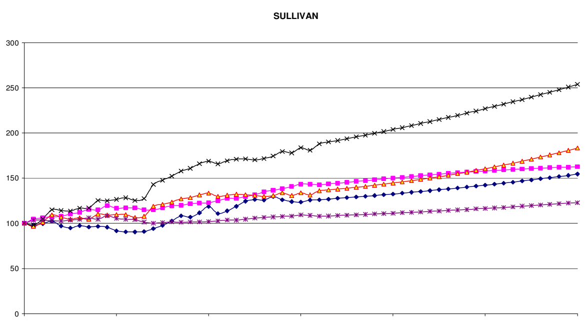
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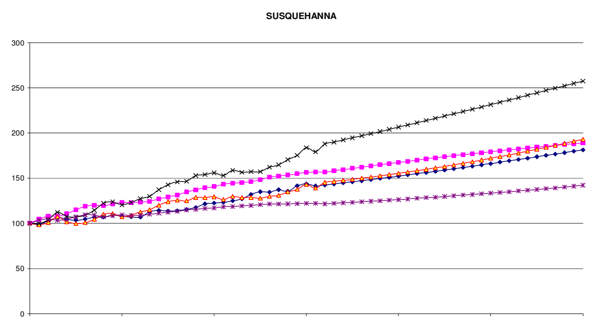
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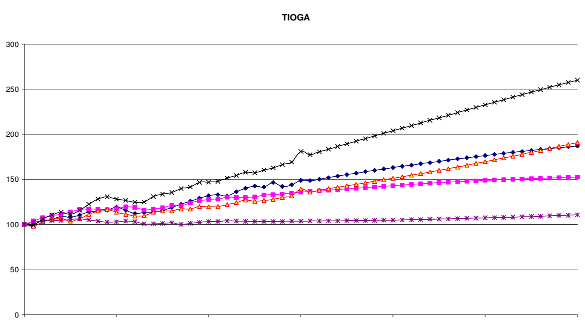
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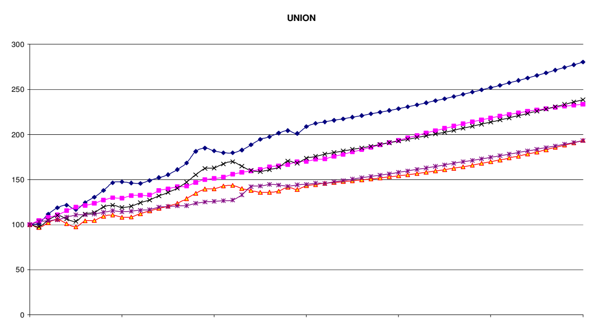
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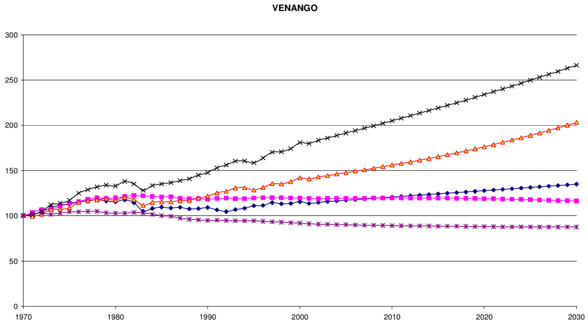
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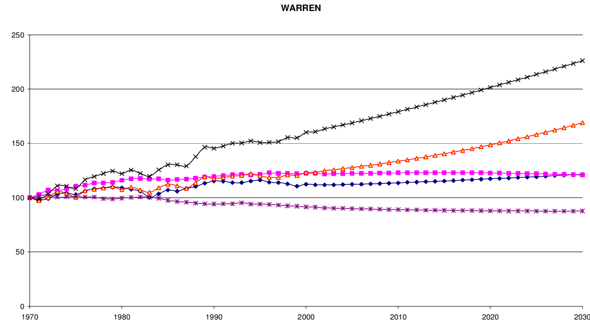
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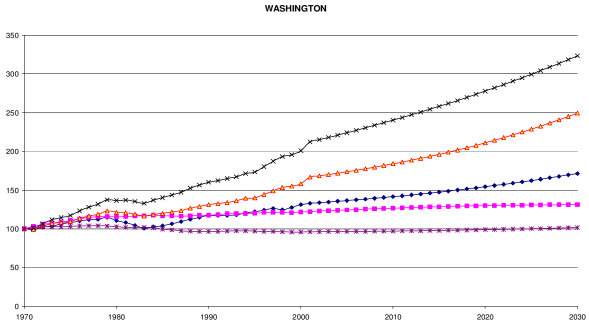
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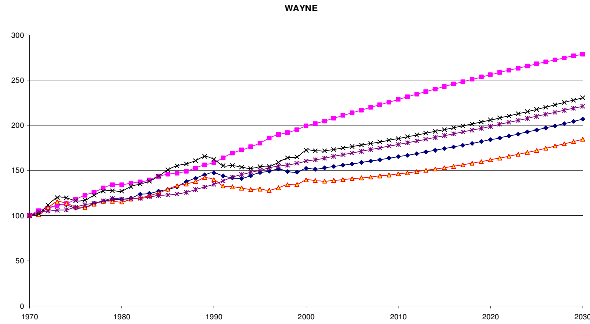
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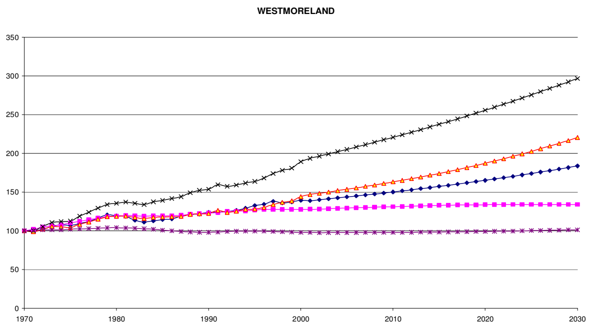
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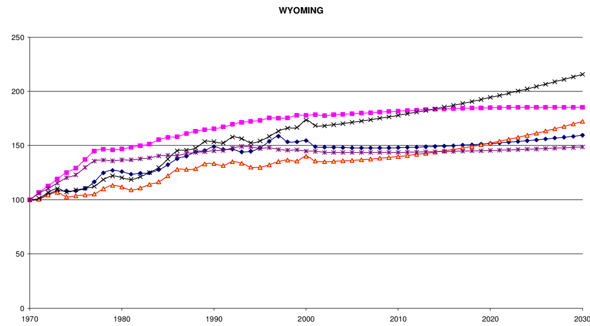
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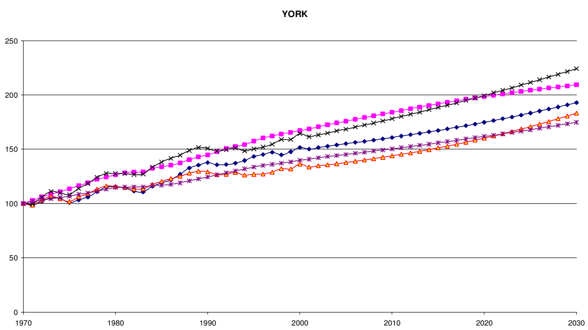
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Appendix C. Model Estimation Results

Table C-1. Estimation Results of County-Level OLS Base Model POP

Dependent Var=LN(VMT)	Rural Interstates		Rural Non-Interstates		Urban Interstates		Urban Non-Interstates	
Adjusted R^2		99.1		97.6		99.7		99.6
N		434		660		421		544
	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
Constant	-62.062	-11.11	4.309	0.63	-45.659	-5.74	-35.761	-5.32
LN (Population)	1.231	8.88	1.2606	6.44	1.23078	27.5	1.90763	48.99
LN (Per Capita Income)	-0.1121	-0.7	0.3606	1.94	0.2062	0.98	-0.6681	-3.6
LN (Lane Miles Per Capita)	0.99697	42.7	1.3765	14.41	0.53263	11.4	0.15485	6.58
Year	0.03766	10.51	0.001285	0.31	0.02603	5.4	0.019822	4.85
County Dummy								
ADAMS	-	-	0.3576	1.36	-	-	0.07477	1.73
ALLEGHENY	-	-	1.0395	3.22	-0.1121	-1.46	-0.47504	-7.6
ARMSTRONG	-	-	-0.3965	-1.33	-0.79277	-10.12	1.00783	18.84
BEAVER	-0.3821	-3.58	0.3783	2.14	-0.09108	-1.69	0.92615	18.36
BEDFORD	0.0001	0	-0.2862	-0.78	-	-	-	-
BERKS	-0.37838	-9.91	0.14665	3	-0.26035	-5.99	0.07778	1.94
BLAIR	-0.8182	-5.39	0.6593	2.95	-0.23662	-4.51	0.97466	19.17
BRADFORD	-	-	-0.9239	-2.85	-0.85161	-10.95	0.20555	4.01
BUCKS	-0.02969	-0.33	0.7053	5.49	0.0164	0.24	0.19327	3.17
BUTLER	-0.2694	-2.41	0.0977	0.66	-0.30961	-6.69	0.52619	12.74
CAMBRIA	-	-	0.4446	2.52	-0.55727	-9.72	0.47954	10.26
CAMERON	-	-	-0.3024	-0.4	-	-	-	-
CARBON	-0.2283	-0.89	0.6504	1.84	-0.44646	-5.49	0.87689	14.95
CENTRE	-0.3943	-2.74	0.3211	1.65	-0.69962	-13.53	0.8366	19.47
CHESTER	0.00528	0.06	0.2487	2.22	0.1011	0.87	0.5516	5.38
CLARION	0.0396	0.13	-0.5346	-1.35	-	-	0.92638	16.32
CLEARFIELD	-0.1933	-0.9	-0.281	-1.01	-0.9998	-9.53	0.65109	12.19
CLINTON	-0.1982	-0.62	-0.0862	-0.21	-0.4076	-4.29	1.38265	19.56
COLUMBIA	0.0648	0.26	-0.4789	-1.48	-0.11576	-1.46	1.48577	23.13
CRAWFORD	-0.535	-2.64	-0.6215	-2.38	-1.3606	-12.52	0.59962	11.91
CUMBERLAND	-0.06771	-0.78	0.3683	2.57	0.4978	7.05	0.84711	14.87
DAUPHIN	0.11566	1.65	0.7319	5.42	0.63557	9.65	0.95437	17.96
DELAWARE	-	-	2.2717	5.69	0.30163	4.64	0.19818	3.37
ELK	-	-	0.1575	0.36	-	-	1.36136	15.28
ERIE	-0.54703	-9.36	0.12955	1.59	-0.50098	-7.68	0.32284	8.02
FAYETTE	-	-	0.0572	0.32	-0.69366	-11.65	0.2385	4.75
FOREST	-	-	-0.4589	-0.59	-	-	-	-
FRANKLIN	-0.0089	-0.06	0.2102	1.04	-0.16195	-2.55	0.61746	14.77
FULTON	-0.0289	-0.06	-0.3284	-0.56	-	-	-	-
GREENE	-0.1502	-0.48	-0.7622	-1.89	-	-	-	-
HUNTINGDON	-0.1768	-0.58	-0.1837	-0.48	-	-	0.60715	9.61
INDIANA	-	-	-0.1854	-0.71	-1.37224	-19.66	0.42349	9.53
JEFFERSON	-0.087	-0.3	-0.4285	-1.13	-	-	0.66308	11.28
JUNIATA	-	-	0.0676	0.13	-	-	-	-
LACKAWANNA	-0.52277	-6.26	0.6015	3.63	0.20056	3.54	0.57895	13.39
LANCASTER	-0.41388	-9.41	0.29998	5.01	-0.10164	-2.26	-0.17803	-4.23
LAWRENCE	-0.3857	-1.99	0.4199	1.57	-0.53642	-8.5	0.80008	13.67
LEBANON	0.0011	0.01	0.5748	2.52	-	-	0.70923	14.8
LEHIGH	-0.1492	-3.29	0.3928	3.62	0.34383	6.77	0.64943	13.71
LUZERNE	-0.51955	-10.86	0.2421	3.06	0.05569	1.4	0.30095	7.34

LYCOMING	-0.6091	-3.71	-0.2367	-1.12	0.18908	3.2	0.86042	16.6
MCKEAN	-	-	-0.0616	-0.16	-0.76842	-8.86	0.5294	8.64
MERCER	-0.4332	-2.67	-0.1708	-0.8	-0.6275	-10.64	0.7786	14.91
MIFFLIN	-	-	0.4553	1.16	-0.09974	-1.12	1.38057	20.34
MONROE	-0.1841	-1.24	0.5178	2.61	0.06767	0.95	-0.12756	-3.32
MONTGOMERY	-0.024	-0.18	0.9742	4.64	0.2855	2.61	0.27375	2.9
MONTOUR	0.3362	0.82	-0.0077	-0.01	-	-	2.8497	21.6
NORTHAMPTON	-	-	0.6477	5.54	0.21349	5.24	0.38764	9.33
NORTHUMBERLAND	-0.4984	-2.57	0.0798	0.31	-0.90343	-10.72	0.89541	16.56
PERRY	-	-	0.2196	0.56	-	-	0.52548	9.84
PHILADELPHIA	-	-	-	-	-0.11273	-1.19	-1.34893	-16.04
PIKE	-0.3231	-1.08	0.6322	1.56	-	-	-	-
POTTER	-	-	-0.9062	-1.66	-	-	-	-
SCHUYLKILL	-0.3159	-2.38	0.3189	1.83	-	-	-0.18439	-4.51
SNYDER	-	-	-0.0097	-0.02	-0.5829	-5.51	2.14174	24.07
SOMERSET	0.0243	0.11	-0.4	-1.42	-0.35753	-4.33	0.51564	10.03
SULLIVAN	-	-	-0.863	-1.18	-	-	-	-
SUSQUEHANNA	-0.061	-0.2	-0.9044	-2.3	-	-	-	-
TIOGA	-	-	-0.5261	-1.32	-	-	-	-
UNION	-0.1749	-0.58	0.4327	1.05	-	-	1.57424	23.59
VENANGO	-0.1347	-0.52	-0.3224	-0.95	-	-	1.60274	22.08
WARREN	-	-	-0.3354	-0.87	-	-	1.52184	21.4
WASHINGTON	-0.218	-2.44	-0.1042	-0.87	0.24642	4.44	0.61151	12.68
WAYNE	-0.3842	-1.32	-0.4162	-1.11	-	-	-	-
WESTMORELAND	-0.2402	-7.56	0.40551	7.24	-0.02488	-0.49	0.23946	5.7
WYOMING	-	-	0.0916	0.19	-	-	-	-
YORK	-	-	-	-	-	-	-	-

Table C-2. Estimation Results of County-Level OLS Base Model HH

Dependent Var=LN(VMT)	**Rural Interstates**		**Rural Non-Interstates**		**Urban Interstates**		**Urban Non-Interstates**	
Adjusted R^2		**99.1**		**97.6**		**99.7**		**99.6**
N		**434**		**660**		**421**		**544**
	Coefficient	**T-stat**	**Coefficient**	**T-stat**	**Coefficient**	**T-stat**	**Coefficient**	**T-stat**
Constant	-52.459	-12.93	9.838	2.07	-37.766	-6.28	-12.264	-2.56
LN (Households)	1.422	9.88	1.5046	7.44	1.2391	27.33	1.92057	49.25
LN (Mean Household Income)	-0.2743	-1.75	0.2075	1.16	0.1663	0.79	-0.6862	-3.82
LN (Lane Miles Per Capita)	0.99463	43.81	1.38995	14.9	0.53123	11.33	0.12889	5.45
Year	0.033239	11.39	-0.001631	-0.48	0.022734	5.84	0.009236	2.96
County Dummy								
ADAMS	-	-	0.7563	2.65	-	-	0.18302	3.98
ALLEGHENY	-	-	0.7311	2.21	-0.18756	-2.51	-0.66649	-10.98
ARMSTRONG	-	-	-0.07	-0.23	-0.81509	-10.4	0.94825	18.08
BEAVER	-0.3002	-2.84	0.5175	2.97	-0.1135	-2.1	0.88474	17.65
BEDFORD	0.3267	1.14	0.1227	0.32	-	-	-	-
BERKS	-0.3335	-8.81	0.18834	3.81	-0.23569	-5.37	0.1212	3.02
BLAIR	-0.6716	-4.4	0.8748	3.9	-0.25585	-4.79	0.92758	18.29
BRADFORD	-	-	-0.5401	-1.6	-0.84257	-10.82	0.21107	4.17
BUCKS	0.03132	0.36	0.7338	5.79	0.09014	1.15	0.36515	5.31
BUTLER	-0.0756	-0.63	0.32	1.99	-0.27092	-5.63	0.59582	14.06
CAMBRIA	-	-	0.6203	3.46	-0.56811	-9.3	0.43355	8.91
CAMERON	-	-	0.5906	0.76	-	-	-	-
CARBON	0.0586	0.23	1.0371	2.89	-0.47148	-5.86	0.8032	14.2
CENTRE	-0.1012	-0.64	0.6678	3.08	-0.60073	-11.11	0.98486	22.29
CHESTER	0.17057	1.76	0.3904	3.41	0.1919	1.5	0.7229	6.62
CLARION	0.4567	1.45	-0.0188	-0.05	-	-	0.94594	16.71
CLEARFIELD	0.0416	0.19	0.0253	0.09	-1.0087	-9.47	0.61932	11.52
CLINTON	0.2012	0.61	0.4275	0.98	-0.392	-4.08	1.37675	19.53
COLUMBIA	0.378	1.49	-0.0745	-0.22	-0.09696	-1.2	1.5013	23.36
CRAWFORD	-0.2725	-1.31	-0.2999	-1.09	-1.3422	-12.26	0.62764	12.53
CUMBERLAND	0.06681	0.73	0.549	3.78	0.52032	7.7	0.8526	16
DAUPHIN	0.13201	2.04	0.8004	6.38	0.59482	9.89	0.84456	17.96
DELAWARE	-	-	2.3275	5.95	0.34996	5.15	0.28725	4.75
ELK	-	-	0.6778	1.52	-	-	1.33115	15.28
ERIE	-0.46161	-7.68	0.23007	2.68	-0.47104	-7.21	0.3819	9.62
FAYETTE	-	-	0.1983	1.11	-0.73132	-11.54	0.15595	2.98
FOREST	-	-	0.4817	0.6	-	-	-	-
FRANKLIN	0.1747	1.13	0.4451	2.14	-0.1643	-2.58	0.59771	14.5
FULTON	0.552	1.2	0.3922	0.64	-	-	-	-
GREENE	0.2982	0.92	-0.2174	-0.51	-	-	-	-
HUNTINGDON	0.2515	0.79	0.3488	0.85	-	-	0.70892	11.14
INDIANA	-	-	0.1667	0.6	-1.32921	-18.76	0.47564	10.7
JEFFERSON	0.2502	0.85	0.0061	0.02	-	-	0.60322	10.48
JUNIATA	-	-	0.7375	1.37	-	-	-	-
LACKAWANNA	-0.47763	-5.82	0.7045	4.4	0.17179	3.05	0.49834	11.68
LANCASTER	-0.35085	-8.84	0.33416	6.02	-0.03799	-0.83	-0.03537	-0.83
LAWRENCE	-0.1601	-0.81	0.7202	2.63	-0.53539	-8.39	0.80385	13.79
LEBANON	0.2265	1.36	0.8602	3.64	-	-	0.72687	15.26
LEHIGH	-0.10672	-2.38	0.4623	4.41	0.34415	7.06	0.62973	13.98
LUZERNE	-0.57815	-12.03	0.22096	2.91	0.00816	0.18	0.17896	4.01

LYCOMING	-0.4284	-2.56	0.0057	0.03	0.19192	3.18	0.85404	16.41
MCKEAN	-	-	0.4169	1.05	-0.75344	-8.67	0.50659	8.47
MERCER	-0.2411	-1.45	0.0813	0.37	-0.61844	-10.19	0.78347	14.9
MIFFLIN	-	-	0.8924	2.21	-0.11142	-1.25	1.35369	20.15
MONROE	0.1241	0.77	0.8458	3.86	0.15305	2.14	0.04836	1.25
MONTGOMERY	-0.0493	-0.39	0.9359	4.57	0.3173	2.88	0.31502	3.39
MONTOUR	0.9538	2.2	0.7597	1.29	-	-	2.8904	22.35
NORTHAMPTON	-	-	0.7805	6.48	0.24624	5.88	0.45056	10.69
NORTHUMBERLAND	-0.3508	-1.83	0.3184	1.23	-0.95214	-10.88	0.76968	13.89
PERRY	-	-	0.7371	1.79	-	-	0.56729	10.33
PHILADELPHIA	-	-	-	-	-0.12683	-1.31	-1.38761	-16.28
PIKE	0.0956	0.31	1.1382	2.7	-	-	-	-
POTTER	-	-	-0.2106	-0.37	-	-	-	-
SCHUYLKILL	-0.224	-1.7	0.4734	2.7	-	-	-0.28745	-6.48
SNYDER	-	-	0.6421	1.41	-0.4798	-4.21	2.33256	24.44
SOMERSET	0.283	1.27	-0.0712	-0.24	-0.3531	-4.21	0.50318	9.76
SULLIVAN	-	-	0.0201	0.03	-	-	-	-
SUSQUEHANNA	0.3369	1.08	-0.4236	-1.03	-	-	-	-
TIOGA	-	-	-0.0294	-0.07	-	-	-	-
UNION	0.5398	1.57	1.2468	2.66	-	-	2.02686	26.96
VENANGO	0.2003	0.76	0.1022	0.29	-	-	1.5931	22.43
WARREN	-	-	0.1138	0.29	-	-	1.45617	21.29
WASHINGTON	-0.13656	-1.53	0.0144	0.12	0.22769	4.25	0.56276	12.2
WAYNE	0.0036	0.01	0.063	0.16	-	-	-	-
WESTMORELAND	-0.30356	-9.3	0.36255	6.57	-0.06374	-1.22	0.15575	3.63
WYOMING	-	-	0.7123	1.44	-	-	-	-
YORK	-	-	-	-	-	-	-	-

Table C-3. Estimation Results of County-Level OLS Base Model HH JrSr

Dependent Var=LN(VMT)	Rural Interstates		Rural Non-Interstates		Urban Interstates		Urban Non-Interstates	
Adjusted R^2		**99.1**		**97.8**		**99.7**		**99.7**
N		**434**		**660**		**421**		**544**
	Coefficient	**T-stat**	**Coefficient**	**T-stat**	**Coefficient**	**T-stat**	**Coefficient**	**T-stat**
Constant	-63.74	-9.89	26.425	3.69	-28.875	-3.5	-11.332	-1.61
LN (Households)	1.3415	8.91	1.2152	5.93	1.5244	6.52	1.7685	8.41
Pop17 (% of Pop<17 yrs)	2.108	2.26	-1.3825	-1.49	-2.006	-1.79	-0.559	-0.55
Pop65+ (% of Pop>65+ yrs)	0.599	0.46	9.117	6.09	-4	-2.2	-2.995	-2.02
LN (Mean Household Income)	-0.3587	-2.23	0.4663	2.61	0.1956	0.89	-0.6987	-3.77
LN(Lane Miles Per Capita)	0.9923	43.83	1.30628	14.4	0.51138	10.15	0.10233	4.04
Year	0.039523	9.8	-0.010259	-2.3	0.016859	3.21	0.00994	2.26
County Dummy								
ADAMS	-	-	0.3714	1.27	-	-	-0.0578	-0.18
ALLEGHENY	-	-	0.3345	1.01	-0.4294	-1.38	-0.3276	-1.22
ARMSTRONG	-	-	-0.8282	-2.51	-0.2093	-0.51	0.8227	2.26
BEAVER	-0.3608	-2.66	-0.1673	-0.83	0.2646	1.32	0.9384	5.32
BEDFORD	0.1443	0.46	-0.5309	-1.34	-	-	-	-
BERKS	-0.33982	-7.63	-0.00325	-0.06	-0.16425	-2.96	0.17079	3.4
BLAIR	-0.7625	-4.34	0.2217	0.9	0.1813	0.68	0.8919	3.72
BRADFORD	-	-	-1.0256	-2.89	-0.2195	-0.5	-0.0171	-0.04
BUCKS	0.07283	0.8	0.7729	6.14	-0.0529	-0.44	0.4146	3.97
BUTLER	-0.1435	-1.13	0.049	0.3	-0.0036	-0.02	0.4965	2.75
CAMBRIA	-	-	-0.1698	-0.78	-0.1292	-0.51	0.4764	2.14
CAMERON	-	-	-0.9609	-1.17	-	-	-	-
CARBON	-0.079	-0.27	0.0842	0.22	0.2025	0.45	0.6557	1.6
CENTRE	-0.0415	-0.26	0.6121	2.91	-0.5437	-2.16	0.6832	3.11
CHESTER	0.20511	2.08	0.3976	3.53	0.1235	0.94	0.7058	6.5
CLARION	0.3047	0.92	-0.6342	-1.49	-	-	0.6057	1.28
CLEARFIELD	-0.089	-0.37	-0.5846	-1.92	-0.4891	-1.25	0.48	1.44
CLINTON	0.0216	0.06	-0.3953	-0.87	0.373	0.68	1.1067	2.23
COLUMBIA	0.2744	1.02	-0.7257	-2.09	0.4404	1.04	1.2934	3.44
CRAWFORD	-0.4256	-1.87	-0.7404	-2.57	-0.8654	-2.28	0.4642	1.46
CUMBERLAND	0.07797	0.8	0.1663	1.1	0.7009	4.73	0.8062	5.99
DAUPHIN	0.10909	1.58	0.5369	4.21	0.7402	7.21	0.83173	9.21
DELAWARE	-	-	1.7794	4.62	0.329	3.18	0.4229	4.67
ELK	-	-	-0.2164	-0.46	-	-	1.0908	2.13
ERIE	-0.51592	-7.63	0.06826	0.74	-0.3409	-2.99	0.37681	4.48
FAYETTE	-	-	-0.41	-1.98	-0.3059	-1.25	0.1543	0.7
FOREST	-	-	-1.0966	-1.29	-	-	-	-
FRANKLIN	0.0815	0.48	-0.0237	-0.11	0.2125	0.78	0.4962	2.06
FULTON	0.2653	0.54	-0.4131	-0.66	-	-	-	-
GREENE	0.1181	0.34	-0.8564	-1.95	-	-	-0.6249	-1.22
HUNTINGDON	0.0853	0.26	-0.1945	-0.47	-	-	0.3706	0.8
INDIANA	-	-	-0.2707	-0.96	-0.9097	-2.61	0.2603	0.83
JEFFERSON	0.0527	0.16	-0.8212	-1.97	-	-	0.3931	0.85
JUNIATA	-	-	-0.0454	-0.08	-	-	-	-
LACKAWANNA	-0.5078	-4.11	-0.0877	-0.44	0.5365	2.9	0.6007	3.78
LANCASTER	-0.38176	-9.1	0.32805	5.94	-0.02569	-0.48	0.01927	0.39
LAWRENCE	-0.2954	-1.26	-0.1619	-0.52	0.0778	0.22	0.7769	2.42
LEBANON	0.1291	0.7	0.2776	1.1	-	-	0.6321	2.42

LEHIGH	-0.11081	-1.88	0.0807	0.7	0.4839	5.63	0.68127	8.9
LUZERNE	-0.56315	-5.92	-0.4435	-3.61	0.2343	1.88	0.3462	3.37
LYCOMING	-0.5432	-2.95	-0.4318	-1.86	0.6202	2.24	0.7593	3.03
MCKEAN	-	-	-0.3496	-0.84	-0.0357	-0.07	0.2623	0.57
MERCER	-0.3488	-1.8	-0.5816	-2.34	-0.132	-0.44	0.7505	2.84
MIFFLIN	-	-	0.1152	0.27	0.6324	1.26	1.1331	2.5
MONROE	-0.0001	-	0.7027	3.17	0.4472	1.59	-0.1708	-0.7
MONTGOMERY	0.0451	0.34	0.6459	3.12	0.174	0.91	0.4877	3.03
MONTOUR	0.7095	1.53	-0.3841	-0.63	-	-	2.5352	3.82
NORTHAMPTON	-	-	0.3952	3.03	0.4217	3.84	0.466	4.66
NORTHUMBERLAND	-0.4594	-2.05	-0.5083	-1.75	-0.4092	-1.15	0.7284	2.37
PERRY	-	-	0.3842	0.92	-	-	0.1528	0.33
PHILADELPHIA	-	-	-	-	-0.4812	-1.51	-1.1498	-3.95
PIKE	-0.1383	-0.41	0.5107	1.16	-	-	-	-
POTTER	-	-	-1.1011	-1.85	-	-	-	-
SCHUYLKILL	-0.2757	-1.62	-0.3349	-1.56	-	-	-0.2544	-1.11
SNYDER	-	-	0.0081	0.02	0.203	0.36	1.9814	3.92
SOMERSET	0.1497	0.6	-0.7885	-2.48	0.2297	0.58	0.3848	1.1
SULLIVAN	-	-	-1.6113	-2.01	-	-	-	-
SUSQUEHANNA	0.111	0.33	-1.0198	-2.38	0.7404	1.39	-0.0124	-0.03
TIOGA	-	-	-0.6519	-1.51	-	-	-	-
UNION	0.4282	1.22	0.6083	1.3	-	-	1.6174	3.23
VENANGO	0.0269	0.09	-0.6057	-1.62	-	-	1.4086	3.44
WARREN	-	-	-0.6258	-1.5	-	-	1.2208	2.64
WASHINGTON	-0.1589	-1.36	-0.5775	-3.87	0.5446	3.1	0.6148	3.95
WAYNE	-0.1934	-0.59	-0.7294	-1.74	-	-	0.0349	0.07
WESTMORELAND	-0.28082	-4.06	-0.11969	-1.36	0.0879	0.83	0.31053	4.11
WYOMING	-	-	0.1409	0.28	-	-	-0.7454	-1.3
YORK	-	-	-	-	-	-	-	-

Table C-4. Estimation Results of County Group Level OLS Base Model HH

Dependent Var=LN(VMT)	**Rural Interstates**		**Rural Non-Interstates**		**Urban Interstates**		**Urban Non-Interstates**	
Adjusted R^2		**99**		**99**		**100**		**100**
N		**110**		**130**		**120**		**130**
	Coefficient	**T-stat**	**Coefficient**	**T-stat**	**Coefficient**	**T-stat**	**Coefficient**	**T-stat**
Constant	-9.203	-4.59	-10.57	-4.01	-2.037	-0.64	0.318	0.15
LN (Households)	1.7318	7.46	4.0981	12.26	1.6203	5.15	2.2667	8.51
LN (Mean Household Income)	1.5384	10.55	-0.2818	-2.01	0.7692	3.82	-0.3778	-2.32
LN (Lane Miles Per Capita)	1.00868	23.28	3.5944	14.8	0.90262	9.65	0.30991	5.64
County Group Dummy								
ALTGR	-0.8023	-2.89	-2.1681	-6.55	ALTGR	0.9106	-1.4089	-4.25
CNTRGR	-0.7058	-3.32	-1.1861	-5	CNTRGR	1.0716	-0.8638	-3.35
EPAGR	-1.6003	-3.83	-0.7787	-1.83	EPAGR	0.8926	-1.7606	-3.51
HARRGR	-1.7356	-3.23	-3.3265	-5.51	HARRGR	0.6105	-2.506	-3.92
I81GR	-1.325	-3.47	-1.8243	-4.51	I81GR	0.8868	-1.7826	-3.88
NCNTGR	-	-	-0.77196	-9.45	NCNTGR	0.7229	-0.46727	-14.43
NEPAGR	-0.32236	-3.73	0.94645	9.51	NEPAGR	2.0861	-1.10514	-11.74
NTIERGR	-	-	-0.6606	-7.56	NTIERGR	1.122	-0.7242	-6.68
PHILY	-2.3944	-3.42	-0.4939	-0.69	PHILY	0.2204	-3.21	-3.85
SEDA-COG	-0.5315	-2.97	-0.8908	-4.49	SEDA-COG	0.9863	-0.7034	-3.22
SHVGR	-1.0437	-3.84	-1.2023	-4.24	SHVGR	0.957	-1.0862	-3.29
SWPAC	-2.3904	-3.66	-4.5742	-6.21	SWPAC	-	-3.0514	-3.88

Table C-5. Estimation Results of County Group Level OLS Base Model HH JrSr

Dependent Var=LN(VMT)	Rural Interstates		Rural Non-Interstates		Urban Interstates		Urban Non-Interstates	
Adjusted R^2		**100**		**99**		**100**		**100**
N		**110**		**130**		**120**		**130**
	Coefficient	**T-stat**	**Coefficient**	**T-stat**	**Coefficient**	**T-stat**	**Coefficient**	**T-stat**
Constant	-7.987	-2.69	-11.706	-3.75	-1.905	-0.43	5.903	1.87
Pop17 (% of Pop<17 yrs)	-1.835	-1.27	1.52	1.2	0.293	0.15	-3.095	-2.04
Pop65+ (% of Pop>65+ yrs)	6.373	2.14	13.547	5.18	-6.089	-1.53	-11.342	-4.01
LN (Households)	1.6844	7.51	3.6237	11.68	1.6515	5.24	2.4337	9.16
LN (Mean Household Income)	1.4228	6.52	-0.03	-0.16	0.7838	2.94	-0.805	-3.8
LN (Lane Miles Per Capita)	1.01674	23.86	3.2502	14.38	0.8651	8.33	0.33997	5.51
County Group Dummy								
ALTGR	-0.8574	-3.2	-1.9107	-6.39	0.9382	1.61	-1.5264	-4.73
CNTRGR	-0.5543	-2.37	-0.5742	-2.36	0.9099	1.35	-1.3634	-4.9
EPAGR	-1.4273	-3.54	-0.4105	-1.06	0.7882	2.22	-2.0842	-4.06
HARRGR	-1.428	-2.71	-2.3925	-4.23	0.3983	1.81	-3.0667	-4.63
I81GR	-1.4552	-3.95	-1.7869	-4.95	1.0185	2.58	-1.8092	-4.03
NCNTGR	-	-	-0.73322	-9.71	0.7016	0.72	-0.39864	-10.87
NEPAGR	-0.1003	-0.89	1.2392	12.01	1.8564	2.03	-1.3505	-12.3
NTIERGR	-	-	-0.54088	-6.68	1.071	1.03	-0.7098	-6.22
PHILY	-1.9824	-2.9	0.1184	0.18	-0.0391	-0.26	-3.8222	-4.43
SEDA-COG	-0.5059	-2.9	-0.6508	-3.56	0.9356	1.29	-0.8886	-4.09
SHVGR	-0.9015	-3.4	-0.8323	-3.18	0.8258	1.35	-1.3637	-3.98
SWPAC	-2.3162	-3.7	-3.9167	-5.86	-	-	-3.3927	-4.31

Table C-6. Estimation Results of County-Level OLS Difference Model HH

Dependent Var=Diff LN(VMT)	Rural Interstates		Rural Non-Interstates		Urban Interstates		Urban Non-Interstates	
Adjusted R^2		78.9		40.3		25		6.3
N		390		594		378		486
	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
Constant	0.0191	0.71	-0.03736	-1.14	0.02839	0.86	0.03152	0.96
Diff LN (Households)	0.2307	0.25	0.2261	0.27	0.843	0.68	1.007	0.93
Diff LN (Mean Household Income)	-0.2157	-0.95	0.5792	2.48	0.3599	1.16	-0.8725	-3.22
Diff LN (Lane Miles Per Capita)	0.99638	36.44	1.81149	19.03	0.57852	11.6	0.17826	6.32
County Dummy								
ADAMS	-	-	0.02996	0.68	-	-	0.0108	0.26
ALLEGHENY	-	-	0.0741	1.65	-0.0154	-0.35	-0.0119	-0.27
ARMSTRONG	-	-	0.02743	0.62	-0.00247	-0.06	0.00538	0.12
BEAVER	0.01456	0.41	0.02519	0.56	-0.01433	-0.33	-0.00352	-0.08
BEDFORD	-0.00327	-0.1	0.03362	0.77	-	-	-	-
BERKS	0.01472	0.43	0.00543	0.13	-0.00263	-0.06	0.00676	0.16
BLAIR	-0.03991	-1.05	0.0175	0.39	-0.00798	-0.18	-0.01282	-0.29
BRADFORD	-	-	0.04084	0.94	-0.06126	-1.49	-0.02113	-0.5
BUCKS	0.02928	0.81	-0.04544	-1.04	-0.02594	-0.63	-0.00072	-0.02
BUTLER	0.02325	0.68	0.02322	0.53	0.0102	0.25	0.00474	0.11
CAMBRIA	-	-	0.03994	0.88	-0.00165	-0.04	-0.02063	-0.46
CAMERON	-	-	0.05324	1.19	-	-	-	-
CARBON	0.0393	1.13	-0.01264	-0.29	0.02583	0.63	0.04495	1.07
CENTRE	0.0279	0.82	0.05333	1.23	0.01268	0.31	-0.00726	-0.17
CHESTER	0.03189	0.91	-0.0031	-0.07	-0.025	-0.59	0.01439	0.34
CLARION	0.0426	1.23	0.03136	0.72	-	-	-0.03312	-0.78
CLEARFIELD	0.02538	0.74	0.04854	1.11	0.02338	0.57	-0.03801	-0.91
CLINTON	0.02691	0.78	0.07183	1.64	-0.00834	-0.2	-0.03995	-0.94
COLUMBIA	0.04226	1.23	0.0436	1	0.02208	0.53	-0.02908	-0.69
CRAWFORD	0.02547	0.74	0.02926	0.67	0.01057	0.25	-0.0245	-0.58
CUMBERLAND	0.02655	0.78	0.02994	0.69	-0.00537	-0.13	-0.01339	-0.32
DAUPHIN	0.02525	0.73	0.03797	0.87	-0.01303	-0.32	-0.01472	-0.35
DELAWARE	-	-	-0.00969	-0.22	0.01107	0.26	-0.02435	-0.57
ELK	-	-	0.07726	1.75	-	-	0.01747	0.41
ERIE	-0.00089	-0.03	0.0366	0.83	0.02932	0.69	-0.00946	-0.22
FAYETTE	-	-	0.01234	0.28	-0.0388	-0.92	0.01143	0.27
FOREST	-	-	0.05884	1.34	-	-	-	-
FRANKLIN	0.02124	0.63	0.04411	1.02	-0.011	-0.27	-0.02674	-0.64
FULTON	0.01461	0.43	0.03892	0.9	-	-	-	-
GREENE	-0.00203	-0.06	0.0341	0.78	-	-	-	-
HUNTINGDON	0.02335	0.68	0.04665	1.07	-	-	-0.02598	-0.62
INDIANA	-	-	0.03511	0.8	0.00185	0.04	-0.05611	-1.33
JEFFERSON	0.03788	1.09	0.04737	1.08	-	-	-0.02524	-0.59
JUNIATA	-	-	0.04149	0.95	-	-	-	-
LACKAWANNA	0.01808	0.51	0.019	0.43	-0.01243	-0.29	-0.00137	-0.03
LANCASTER	0.03005	0.89	0.00473	0.11	-0.00976	-0.24	0.01952	0.47
LAWRENCE	0.02381	0.68	0.01292	0.29	0.01083	0.25	-0.02417	-0.56
LEBANON	0.03345	0.98	0.05122	1.18	-	-	0.01139	0.27
LEHIGH	-0.01321	-0.39	-0.01277	-0.29	-0.00423	-0.1	-0.01742	-0.42
LUZERNE	0.00716	0.2	-0.01634	-0.37	-0.01705	-0.39	-0.01506	-0.34
LYCOMING	0.02333	0.66	0.01178	0.27	0.01121	0.26	0.02488	0.58

MCKEAN	-	-	0.05795	1.29	-0.0277	-0.63	-0.01917	-0.44
MERCER	0.03348	0.95	0.0385	0.87	0.00685	0.16	-0.01001	-0.23
MIFFLIN	-	-	0.06068	1.38	-0.02183	-0.52	-0.02446	-0.57
MONROE	0.02006	0.51	0.03218	0.69	-0.02579	-0.53	0.0266	0.56
MONTGOMERY	0.01671	0.46	-0.11667	-2.69	-0.01041	-0.26	-0.00879	-0.21
MONTOUR	0.04069	1.18	0.0487	1.11	-	-	-0.04033	-0.96
NORTHAMPTON	-	-	0.0055	0.13	0.00846	0.21	0.00604	0.15
NORTHUMBERLAND	0.03174	0.88	0.04863	1.09	-0.08931	-2.05	-0.03347	-0.76
PERRY	-	-	0.03833	0.88	-	-	0.06937	1.67
PHILADELPHIA	-	-	-	-	-0.01045	-0.23	-0.01914	-0.43
PIKE	0.01429	0.34	0.05388	1.1	-	-	-	-
POTTER	-	-	0.04231	0.97	-	-	-	-
SCHUYLKILL	0.03662	1.02	0.03525	0.79	-	-	-0.00847	-0.19
SNYDER	-	-	0.05118	1.17	0.0172	0.42	-0.01563	-0.37
SOMERSET	0.00826	0.24	0.03793	0.86	-0.00208	-0.05	0.00407	0.1
SULLIVAN	-	-	0.04921	1.13	-	-	-	-
SUSQUEHANNA	0.02726	0.8	0.02726	0.63	-	-	-	-
TIOGA	-	-	0.05724	1.31	-	-	-	-
UNION	0.0146	0.43	0.06142	1.42	-	-	-0.04064	-0.98
VENANGO	0.03359	0.94	0.04268	0.96	-	-	-0.02516	-0.58
WARREN	-	-	0.06451	1.45	-	-	-0.04329	-1
WASHINGTON	0.0067	0.19	0.01956	0.44	-0.00204	-0.05	-0.0027	-0.06
WAYNE	0.01725	0.5	0.03459	0.79	-	-	-	-
WESTMORELAND	0.00474	0.14	0.00585	0.13	-0.00474	-0.11	0.00265	0.06
WYOMING	-	-	0.0313	0.71	-	-	-	-
YORK	-	-	-	-	-	-	-	-

Table C-7. Estimation Results of County-Level OLS Difference Model HH JrSr

Dependent Var=Diff LN(VMT)	Rural Interstates		Rural Non-Interstates		Urban Interstates		Urban Non-Interstates	
Adjusted R^2		79.3		42.8		24.7		11.6
N		390		594		378		486
	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
Constant	-0.5042	-1.87	-1.0917	-4.06	-0.0585	-0.19	1.2415	4.43
Pop17 (% of Pop<17 yrs)	1.7419	2.92	2.705	4.93	0.6563	0.87	-3.2193	-5.11
Pop65+ (% of Pop>65+ yrs)	0.828	0.55	3.102	2.12	-0.503	-0.27	-3.329	-2.11
Diff LN (Households)	-0.758	-0.77	-1.355	-1.46	0.423	0.32	2.585	2.3
Diff LN (Mean Household Income)	-0.3188	-1.4	0.3693	1.59	0.3254	1.04	-0.625	-2.33
Diff LN (Lane Miles Per Capita)	0.98419	35.83	1.75303	18.56	0.58859	11.2	0.16173	5.87
County Dummy								
ADAMS	-	-	0.01757	0.41	-	-	0.02552	0.61
ALLEGHENY	-	-	-0.01599	-0.21	0.0184	0.2	0.07185	0.92
ARMSTRONG	-	-	-0.08634	-1.13	0.02677	0.29	0.12047	1.5
BEAVER	-0.00708	-0.09	-0.09908	-1.23	0.01663	0.17	0.12191	1.44
BEDFORD	-0.01518	-0.27	-0.04167	-0.69	-	-	-	-
BERKS	0.00028	0.01	-0.04865	-1	0.00499	0.1	0.06434	1.34
BLAIR	-0.05578	-0.83	-0.08795	-1.26	0.01551	0.19	0.09377	1.29
BRADFORD	-	-	-0.06144	-1.15	-0.06016	-1.07	0.09217	1.74
BUCKS	0.02539	0.66	-0.03221	-0.71	-0.03596	-0.78	-0.01245	-0.28
BUTLER	0.02396	0.66	0.00963	0.22	0.01698	0.39	0.01933	0.45
CAMBRIA	-	-	-0.09616	-1	0.0426	0.35	0.114	1.1
CAMERON	-	-	-0.1628	-1.6	-	-	-	-
CARBON	0.03724	0.46	-0.11178	-1.36	0.0643	0.63	0.14258	1.63
CENTRE	0.16764	2.23	0.32759	4.15	0.03878	0.44	-0.32177	-4
CHESTER	0.0332	0.79	0.02874	0.59	-0.03832	-0.72	-0.01627	-0.33
CLARION	0.06595	1.64	0.04036	0.86	-	-	-0.0528	-1.12
CLEARFIELD	0.01937	0.32	-0.02614	-0.4	0.04935	0.64	0.03676	0.55
CLINTON	0.03054	0.51	0.01387	0.22	0.02039	0.27	0.01484	0.22
COLUMBIA	0.07392	1.46	0.04562	0.84	0.05386	0.83	-0.0425	-0.75
CRAWFORD	-0.00395	-0.09	-0.05573	-1.06	0.01611	0.29	0.06672	1.27
CUMBERLAND	0.06017	1.48	0.05708	1.21	0.01795	0.35	-0.05037	-1.07
DAUPHIN	0.01872	0.52	0.01181	0.27	-0.00946	-0.22	0.01204	0.28
DELAWARE	-	-	-0.09355	-1.74	0.0189	0.33	0.06126	1.15
ELK	-	-	-0.0489	-0.72	-	-	0.15094	2.15
ERIE	-0.03234	-0.84	-0.03171	-0.69	0.02388	0.51	0.06528	1.45
FAYETTE	-	-	-0.10542	-1.33	-0.00804	-0.08	0.13123	1.56
FOREST	-	-	-0.1065	-1	-	-	-	-
FRANKLIN	0.01031	0.21	-0.01835	-0.34	0.00442	0.07	0.0387	0.7
FULTON	0.00123	0.03	-0.001	-0.02	-	-	-	-
GREENE	0.00906	0.21	0.01692	0.35	-	-	-	-
HUNTINGDON	0.05104	1.31	0.06647	1.45	-	-	-0.05537	-1.22
INDIANA	-	-	0.05275	1.13	0.02333	0.46	-0.08365	-1.78
JEFFERSON	0.00392	0.05	-0.08614	-1.14	-	-	0.11524	1.47
JUNIATA	-	-	-0.02262	-0.46	-	-	-	-
LACKAWANNA	0.00278	0.03	-0.11637	-1.24	0.0299	0.25	0.1336	1.32
LANCASTER	-0.01121	-0.3	-0.06905	-1.53	-0.02144	-0.48	0.10552	2.41
LAWRENCE	-0.01246	-0.13	-0.15123	-1.62	0.0447	0.38	0.14698	1.48
LEBANON	0.01908	0.36	-0.02509	-0.43	-	-	0.09039	1.52
LEHIGH	-0.02194	-0.45	-0.0749	-1.37	0.01147	0.19	0.04489	0.81

LUZERNE	0.00235	0.02	-0.14063	-1.45	0.0315	0.25	0.106	1.01
LYCOMING	0.00118	0.02	-0.0664	-1.22	0.02197	0.36	0.10576	1.92
MCKEAN	-	-	-0.04273	-0.68	-0.0119	-0.16	0.0848	1.32
MERCER	0.00591	0.08	-0.08906	-1.15	0.03294	0.35	0.1221	1.5
MIFFLIN	-	-	-0.06121	-0.94	-0.00878	-0.12	0.1059	1.58
MONROE	0.02027	0.5	0.05415	1.14	-0.03444	-0.66	0.01088	0.23
MONTGOMERY	0.01195	0.28	-0.14966	-3.06	0.00315	0.06	0.02329	0.48
MONTOUR	0.01026	0.17	-0.06288	-0.96	-	-	0.07824	1.16
NORTHAMPTON	-	-	-0.03393	-0.65	0.02678	0.46	0.04366	0.83
NORTHUMBERLAND	0.01703	0.19	-0.07934	-0.89	-0.0503	-0.44	0.09426	0.98
PERRY	-	-	0.04838	1.04	-	-	0.06252	1.36
PHILADELPHIA	-	-	-	-	-0.02068	-0.43	0.06594	1.42
PIKE	-0.00102	-0.02	0.00355	0.06	-	-	-	-
POTTER	-	-	-0.0945	-1.5	-	-	-	-
SCHUYLKILL	0.0326	0.32	-0.09101	-0.92	-	-	0.1141	1.06
SNYDER	-	-	0.03303	0.77	0.0168	0.41	0.00303	0.07
SOMERSET	-0.00489	-0.07	-0.06794	-0.88	0.02992	0.32	0.11003	1.35
SULLIVAN	-	-	-0.1136	-0.94	-	-	-	-
SUSQUEHANNA	-0.01154	-0.25	-0.07033	-1.33	-	-	-	-
TIOGA	-	-	-0.01246	-0.23	-	-	-	-
UNION	0.09002	2.12	0.17949	3.69	-	-	-0.18022	-3.72
VENANGO	-0.00347	-0.06	-0.07313	-1.18	-	-	0.09784	1.54
WARREN	-	-	-0.04495	-0.72	-	-	0.07176	1.12
WASHINGTON	0.00412	0.06	-0.06759	-0.9	0.03308	0.35	0.08175	1.02
WAYNE	0.00325	0.05	-0.06016	-0.84	-	-	-	-
WESTMORELAND	0.00247	0.03	-0.08695	-1.1	0.03343	0.34	0.09232	1.09
WYOMING	-	-	0.00152	0.03	-	-	-	-
YORK	-	-	-	-	-	-	-	-

Table C-8. Estimation Results of County-Level OLS Truck Model HH

Dependent Var=LN(VMT)	Rural Interstates		Rural Non-Interstates		Urban Interstates		Urban Non-Interstates	
Adjusted R^2		98.8		97.6		99.7		99.6
N		434		660		421		544
	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
Constant	-8.503	-5.9	7.712	4.39	-7.034	-3.35	2.016	1.12
LN (Households)	1.923	12.15	1.4747	7.67	1.624	7.17	1.7676	9.11
LN (Mean Household Income)	1.2242	12.56	0.13562	1.38	1.141	10.01	-0.15223	-1.55
LN (Lane Miles Per Capita)	0.99677	38.03	1.38644	14.92	0.61115	12.47	0.1099	4.51
County Dummy								
ADAMS	-	-	0.711	2.65	-	-	-0.0374	-0.13
ALLEGHENY	-	-	0.7689	2.39	-0.8664	-2.98	-0.5341	-2.15
ARMSTRONG	-	-	-0.1271	-0.45	0.0448	0.12	0.7952	2.59
BEAVER	0.2142	1.94	0.4869	3	0.2094	1.38	0.8561	6.44
BEDFORD	1.7804	5.98	0.0466	0.14	-	-	-	-
BERKS	-0.39204	-9.05	0.19045	3.87	-0.23768	-4.87	0.09174	2.28
BLAIR	0.0931	0.59	0.8314	4.05	0.3036	1.33	0.8652	4.42
BRADFORD	-	-	-0.6043	-1.94	0.0882	0.22	0.0455	0.13
BUCKS	-0.68054	-9.71	0.7655	7.08	-0.39489	-4.91	0.25572	3.61
BUTLER	0.3489	2.67	0.2964	1.94	0.0462	0.25	0.4797	2.94
CAMBRIA	-	-	0.5795	3.67	0.02	0.1	0.4208	2.6
CAMERON	-	-	0.4636	0.64	-	-	-	-
CARBON	1.1952	4.33	0.9731	2.92	0.42	1.02	0.6012	1.72
CENTRE	0.5782	3.41	0.6299	3.13	-0.0741	-0.3	0.8644	4.06
CHESTER	-0.71122	-10.63	0.43159	5.68	-0.41257	-6.11	0.43653	7.07
CLARION	1.8985	5.7	-0.0958	-0.25	-	-	0.7069	1.67
CLEARFIELD	1.1929	5.37	-0.0348	-0.14	-0.0353	-0.1	0.5296	1.89
CLINTON	1.766	5.15	0.3434	0.86	0.7469	1.49	1.1698	2.7
COLUMBIA	1.5895	5.99	-0.1397	-0.45	0.8426	2.13	1.3531	4.06
CRAWFORD	0.7824	3.64	-0.3547	-1.42	-0.4214	-1.22	0.5223	1.92
CUMBERLAND	0.188	1.79	0.5382	3.76	0.5708	4.05	0.7179	5.77
DAUPHIN	0.19651	2.65	0.7927	6.38	0.59408	6.22	0.76201	9.13
DELAWARE	-	-	2.342	6.01	-0.02856	-0.39	0.20421	3.1
ELK	-	-	0.606	1.44	-	-	1.0232	2.26
ERIE	-0.18907	-2.97	0.21446	2.7	-0.1843	-1.79	0.38299	5.58
FAYETTE	-	-	0.1536	1	-0.105	-0.55	0.1675	1.02
FOREST	-	-	0.3341	0.45	-	-	-	-
FRANKLIN	0.8477	5.16	0.4081	2.11	0.4023	1.61	0.4822	2.33
FULTON	2.5166	5.1	0.2853	0.5	-	-	-	-
GREENE	1.8973	5.63	-0.3017	-0.78	-	-	-0.4743	-1.05
HUNTINGDON	1.9166	5.91	0.2614	0.71	-	-	0.5652	1.39
INDIANA	-	-	0.1126	0.45	-0.528	-1.62	0.3471	1.25
JEFFERSON	1.6151	5.18	-0.0667	-0.19	-	-	0.3907	0.99
JUNIATA	-	-	0.6423	1.28	-	-	-	-
LACKAWANNA	-0.09062	-1.05	0.6799	4.48	0.3911	3.27	0.4736	4.53
LANCASTER	-0.54173	-13.04	0.3435	6.62	-0.13904	-2.7	-0.04903	-1.08
LAWRENCE	0.8304	4.05	0.6655	2.67	0.1851	0.62	0.7137	2.79
LEBANON	0.8712	4.84	0.8226	3.69	-	-	0.5769	2.56
LEHIGH	-0.17257	-3.36	0.4617	4.41	0.29056	4.54	0.55237	9.51
LUZERNE	-0.33192	-6.7	0.20679	2.96	0.174	3.87	0.24164	5.71
LYCOMING	0.4242	2.46	-0.0391	-0.2	0.7802	3.2	0.7904	3.72

MCKEAN	-	-	0.3454	0.94	0.237	0.51	0.2724	0.68
MERCER	0.6204	3.63	0.0353	0.18	0.0428	0.17	0.7236	3.41
MIFFLIN	-	-	0.8116	2.21	0.9534	2.13	1.1923	3.07
MONROE	0.8017	4.64	0.8081	3.95	0.744	2.79	-0.0961	-0.43
MONTGOMERY	-1.15526	-12.04	0.9854	5.56	-0.4549	-3.55	0.1547	1.4
MONTOUR	2.2644	4.7	0.6825	1.21	-	-	2.3562	3.92
NORTHAMPTON	-	-	0.7696	6.51	0.34954	3.66	0.38508	4.6
NORTHUMBERLAND	0.6863	3.51	0.2628	1.14	-0.1019	-0.34	0.7063	2.88
PERRY	-	-	0.6679	1.73	-	-	0.2645	0.62
PHILADELPHIA	-	-	-	-	-0.513	-1.61	-1.1271	-4.05
PIKE	1.5006	4.6	1.0602	2.72	-	-	-	-
POTTER	-	-	-0.3044	-0.57	-	-	-	-
SCHUYLKILL	0.5423	4.15	0.4328	2.82	-	-	-0.3088	-1.88
SNYDER	-	-	0.5792	1.33	0.4075	0.74	1.9398	4.15
SOMERSET	1.4223	6.2	-0.1304	-0.49	0.5573	1.6	0.3923	1.35
SULLIVAN			-0.1165	-0.17	-	-	-	-
SUSQUEHANNA	1.7133	5.17	-0.4962	-1.3	1.0612	2.16	0.0358	0.08
TIOGA	-	-	-0.11	-0.29	-	-	-	-
UNION	1.9547	5.29	1.1673	2.67	-	-	1.7253	3.71
VENANGO	1.2221	4.24	0.046	0.14	-	-	1.3479	3.75
WARREN	-	-	0.0454	0.12	-	-	1.2082	2.99
WASHINGTON	0.158	1.6	-0.0021	-0.02	0.4032	2.98	0.4884	4.1
WAYNE	1.3953	4.4	-0.011	-0.03	-	-	0.0712	0.18
WESTMORELAND	-0.22319	-6.07	0.35775	6.59	-0.06669	-1.19	0.20891	4.92
WYOMING	-	-	0.6268	1.35	-	-	-0.5932	-1.15
YORK	-	-	-	-	-	-	-	-

Table C-9. Estimation Results of County-Level OLS Truck Model RETAIL

Dependent Var=LN(VMT)	**Rural Interstates**		**Rural Non-Interstates**		**Urban Interstates**		**Urban Non-Interstates**	
Adjusted R^2		**98.9**		**97.5**		**99.7**		**99.6**
N		**434**		**660**		**421**		**544**
	Coefficient	**T-stat**	**Coefficient**	**T-stat**	**Coefficient**	**T-stat**	**Coefficient**	**T-stat**
Constant	1.4964	1.67	16.546	16.35	0.739	0.58	12.889	12.31
LN (Retail Sales)	1.19394	29.67	0.43155	8.68	1.08228	20.77	0.37588	8.18
LN (Lane Miles Per Capita)	0.98354	38.96	1.22066	13.61	0.57064	12.21	0.07185	2.9
County Dummy								
ADAMS	-	-	-0.546	-5.23	-	-	-1.99877	-20.98
ALLEGHENY	-	-	1.5481	5.2	-0.02854	-0.36	1.25531	17.22
ARMSTRONG	-	-	-1.4918	-12.01	-0.6957	-6.42	-1.31795	-13.56
BEAVER	0.00324	0.06	-0.18758	-1.95	0.12641	1.58	0.06558	0.97
BEDFORD	0.0208	0.19	-1.8127	-12.06	-	-	-	-
BERKS	-0.4124	-9.81	0.11283	2.35	-0.27659	-6.22	0.0014	0.04
BLAIR	-0.96643	-16.09	-0.35317	-4.83	-0.55169	-8.66	-0.58949	-9.77
BRADFORD	-	-	-2.1866	-14.25	-1.0483	-9.96	-2.42342	-25.7
BUCKS	-0.43437	-7.01	0.8567	7.83	-0.19894	-3.55	0.61418	11.71
BUTLER	-0.25015	-4.76	-0.48434	-7.46	-0.40673	-6.81	-0.66292	-12.24
CAMBRIA	-	-	-0.26812	-4.03	-0.56272	-8.4	-0.70954	-11.48
CAMERON	-	-	-3.2473	-13.64	-	-	-	-
CARBON	0.3247	2.92	-0.6643	-5.64	-0.2034	-1.62	-1.741	-15.43
CENTRE	-0.36423	-5.6	-0.48782	-7.06	-0.82649	-12.29	-0.68178	-10.97
CHESTER	-0.5612	-12.45	0.28768	4.8	-0.24179	-4.86	0.25182	5.4
CLARION	0.1663	1.45	-2.1414	-14.31	-	-	-2.3589	-20.99
CLEARFIELD	-0.21179	-2.45	-1.4516	-12.71	-1.2303	-11.73	-1.54781	-19.7
CLINTON	-0.0796	-0.68	-1.8269	-12.94	-0.6805	-5.03	-1.9682	-16.89
COLUMBIA	0.12068	1.38	-1.8335	-16.68	-0.3245	-3.19	-1.05942	-11.33
CRAWFORD	-0.25995	-3.09	-1.5908	-13.01	-1.2944	-11.27	-1.39538	-16.38
CUMBERLAND	-0.52361	-10.06	-0.27779	-4.44	0.01298	0.22	-0.23099	-5.48
DAUPHIN	-0.08578	-2.25	0.26941	3.19	0.42107	7.15	0.22968	5.26
DELAWARE	-	-	1.9798	5.06	0.3919	8.11	0.62676	14.29
ELK	-	-	-1.487	-10.29	-	-	-2.0755	-15.59
ERIE	-0.55416	-11.09	-0.17468	-3.34	-0.54069	-8.39	-0.06271	-1.49
FAYETTE	-	-	-0.6476	-8.72	-0.69078	-9.96	-0.97397	-15.21
FOREST	-	-	-3.5511	-12.94	-	-	-	-
FRANKLIN	0.10131	1.45	-0.59559	-8.01	-0.20138	-2.66	-0.96774	-14.64
FULTON	0.6005	3.32	-2.5782	-12.36	-	-	-	-
GREENE	0.2624	2.18	-2.3079	-14.23	-	-	-3.639	-23.43
HUNTINGDON	0.3799	3.43	-1.6277	-10.59	-	-	-2.2864	-18.43
INDIANA	-	-	-1.2123	-10.74	-1.47113	-16.53	-1.66098	-20.54
JEFFERSON	0.2878	2.5	-1.8761	-12.85	-	-	-2.3708	-20.34
JUNIATA	-	-	-1.9004	-10.69	-	-	-	-
LACKAWANNA	-0.55309	-11.52	-0.01298	-0.13	0.05345	0.81	-0.23662	-4.87
LANCASTER	-0.54721	-14.51	0.40278	7.94	-0.17745	-3.63	0.07804	1.82
LAWRENCE	-0.05448	-0.7	-0.62506	-6.91	-0.46774	-4.83	-1.04583	-11.89
LEBANON	-0.12401	-1.9	-0.42245	-6.08	-	-	-1.06957	-17.18
LEHIGH	-0.47971	-13.69	0.04324	0.53	0.04862	1.15	0.18298	4.57
LUZERNE	-0.48285	-10.1	0.02341	0.36	0.03307	0.8	0.13652	3.29
LYCOMING	-0.69665	-12.47	-1.14617	-13.59	-0.08963	-1.18	-0.77754	-11.99
MCKEAN	-	-	-1.5106	-11.14	-0.6957	-5.18	-2.5071	-21.19

MERCER	-0.59688	-8.23	-1.14228	-15.17	-0.9707	-14.92	-0.88243	-14.3
MIFFLIN	-	-	-1.2221	-10.74	-0.3301	-2.62	-1.6085	-14.81
MONROE	-0.22652	-3.42	-0.35228	-5.15	-0.11813	-1.59	-1.73008	-27.36
MONTGOMERY	-0.53229	-7.52	1.2289	6.86	0.06839	1.02	0.86094	13.87
MONTOUR	0.4748	3.3	-2.2142	-13.94	-	-	-1.827	-11.94
NORTHAMPTON	-	-	0.37296	4.37	0.41965	8.13	-0.05514	-1.12
NORTHUMBERLAND	-0.18281	-2.34	-0.92171	-10.07	-0.8003	-8	-0.98064	-11.42
PERRY	-	-	-1.1422	-7.57	-	-	-2.5956	-19.29
PHILADELPHIA	-	-	-	-	0.59127	7.5	0.9821	16.02
PIKE	0.5088	3.8	-0.831	-5.95	-	-	-	-
POTTER	-	-	-2.8779	-12.88	-	-	-	-
SCHUYLKILL	0.00302	0.04	-0.31612	-4.28	-	-	-1.41157	-21.35
SNYDER	-	-	-1.7783	-14.16	-0.9998	-8.34	-1.444	-13.31
SOMERSET	0.35489	3.87	-1.4377	-11.13	-0.2934	-2.82	-1.64469	-17.93
SULLIVAN			-3.5929	-13.37	-	-	-	-
SUSQUEHANNA	0.5555	4.37	-2.2768	-12.99	0.2468	1.49	-2.8607	-18.83
TIOGA	-	-	-2.0544	-11.79	-	-	-	-
UNION	0.2694	2.28	-1.1679	-8.97	-	-	-1.5748	-12.68
VENANGO	0.08747	0.9	-1.6245	-13.32	-	-	-1.1465	-10.98
WARREN	-	-	-2.1803	-16.64	-	-	-1.9345	-23.86
WASHINGTON	-0.01467	-0.27	-0.47646	-7.81	0.32924	4.72	-0.23693	-4.19
WAYNE	-0.38778	-4.15	-1.9874	-14.08	-	-	-2.8189	-21.36
WESTMORELAND	-0.19209	-5.49	0.35469	6.43	-0.01626	-0.31	0.29936	7.06
WYOMING	-	-	-1.8387	-12.09	-	-	-4.2776	-27.17
YORK	-	-	-	-	-	-	-	-

Table C-10. Estimation Results of County Group Level OLS Base Model Pop wo 2003 data

Dependent Var=LN(VMT)	Rural Interstates		Rural Non-Interstates		Urban Interstates		Urban Non-Interstates	
Adjusted R^2		99.10%		99.20%		99.80%		99.90%
N		390		594		378		486
	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
Constant	-67.322	-10.56	-14.188	-3.17	-46.378	-5.74	-5.678	-1.25
LN (Per Capita Income)	-0.1777	-1.03	-0.0402	-0.35	0.1622	0.8	-0.3934	-3.42
LN (Population)	1.1651	7.51	0.4645	3.65	0.9702	4.29	0.5152	4.1
LN (Lane Miles Per Capita)	0.94768	34.8	0.03929	0.57	0.38197	3.96	-0.00022	-0.01
Year	0.040849	10.14	0.014849	5.48	0.027683	5.71	0.011902	4.48
County Dummy								
ADAMS	-	-	0.1583	0.94	-	-	-2.0969	-11.12
ALLEGHENY	-	-	-2.5598	-11.52	0.2947	0.98	1.2879	8.1
ARMSTRONG	-	-	-0.1937	-1.02	-1.3331	-3.27	-1.2917	-6.21
BEAVER	-0.4654	-3.93	-0.9753	-8.33	-0.1535	-1.05	0.07611	0.85
BEDFORD	-0.0261	-0.08	0.1127	0.48	-	-	-	-
BERKS	-0.34967	-8.7	0.01354	0.47	-0.3142	-5.74	0.02621	1.1
BLAIR	-0.8271	-4.92	-0.5214	-3.59	-0.5026	-2.08	-0.4079	-3.07
BRADFORD	-	-	-0.2034	-0.98	-1.3221	-3.2	-2.3638	-10.3
BUCKS	-0.0873	-0.89	-0.38735	-4.6	0.1824	1.5	0.80642	12.16
BUTLER	-0.2898	-2.33	0.02278	0.24	-0.4981	-2.83	-0.5875	-5.74
CAMBRIA	-	-	-0.11	-0.98	-0.8584	-3.71	-0.667	-5.94
CAMERON	-	-	-1.0048	-2.08	-	-	-	-
CARBON	-0.2782	-0.98	-0.3787	-1.66	-1.0464	-2.34	-1.7905	-7.6
CENTRE	-0.4137	-2.57	-0.078	-0.62	-0.9997	-4.1	-0.5856	-4.46
CHESTER	-0.01857	-0.19	0.02875	0.43	0.228	1.94	0.60291	9.52
CLARION	-0.0232	-0.07	-0.362	-1.43	-	-	-2.234	-7.93
CLEARFIELD	-0.2227	-0.93	-0.0482	-0.27	-1.6401	-3.73	-1.4178	-7.36
CLINTON	-0.2615	-0.74	-0.3053	-1.14	-0.9592	-1.89	-1.7918	-6.18
COLUMBIA	-0.0139	-0.05	-0.7024	-3.4	-0.6476	-1.52	-0.8777	-3.97
CRAWFORD	-0.5847	-2.6	-0.1875	-1.12	-2.0065	-4.62	-1.3691	-7.52
CUMBERLAND	-0.03736	-0.38	-0.60075	-6.35	0.4914	3.96	0.08851	1.14
DAUPHIN	0.05095	0.66	-0.54278	-5.96	0.67988	6.9	0.45177	7.8
DELAWARE	-	-	-3.1347	-11.02	0.38918	4	0.72977	12.41
ELK	-	-	-0.2575	-0.93	-	-	-1.8883	-6.36
ERIE	-0.51398	-8.16	-0.3604	-6.94	-0.7669	-4.88	-0.0188	-0.44
FAYETTE	-	-	-0.0801	-0.7	-0.9526	-4.25	-1.0232	-8.55
FOREST	-	-	-0.3804	-0.76	-	-	-	-
FRANKLIN	-0.0228	-0.14	-0.0955	-0.74	-0.5406	-1.89	-0.8958	-6.48
FULTON	-0.0831	-0.17	-0.4773	-1.26	-	-	-	-
GREENE	-0.1961	-0.57	-0.4852	-1.89	-	-	-	-
HUNTINGDON	-0.3676	-1.09	-0.0781	-0.32	-	-	-2.3771	-8.79
INDIANA	-	-	0.0887	0.53	-1.8162	-5.2	-1.6131	-8.76
JEFFERSON	-0.155	-0.48	-0.3259	-1.35	-	-	-2.3167	-8.66
JUNIATA	-	-	-0.2317	-0.71	-	-	-	-
LACKAWANNA	-0.53078	-5.79	-0.9381	-8.42	0.1888	1.61	-0.12177	-1.69
LANCASTER	-0.41581	-8.87	0.21677	5.93	-0.08665	-1.54	0.08782	2.54
LAWRENCE	-0.4611	-2.14	-0.4566	-2.66	-0.8773	-2.86	-0.984	-5.74
LEBANON	-0.0328	-0.18	-0.3011	-2.05	-	-	-0.9135	-6.23
LEHIGH	-0.15625	-3.23	-0.71046	-9.78	0.35018	5.95	0.38744	10.38
LUZERNE	-0.48659	-9.6	-0.51718	-9.82	0.03645	0.74	0.17046	5.68

LYCOMING	-0.7028	-3.85	-0.1913	-1.43	-0.0502	-0.21	-0.6649	-4.65
MCKEAN	-	-	-0.2946	-1.21	-1.3061	-2.75	-2.4442	-9.17
MERCER	-0.4424	-2.45	-0.3646	-2.69	-1.0023	-3.61	-0.6968	-4.89
MIFFLIN	-	-	-0.5154	-2.03	-0.5894	-1.28	-1.4718	-5.59
MONROE	-0.2082	-1.25	0.1387	1.08	-0.3408	-1.15	-1.7375	-12.44
MONTGOMERY	-0.0512	-0.35	-0.9677	-6.93	0.5327	2.82	1.1593	11.48
MONTOUR	0.2389	0.52	-1.0076	-2.79	-	-	-1.3883	-3.61
NORTHAMPTON	-	-	-0.41265	-5.3	0.14883	1.8	-0.06801	-1.38
NORTHUMBERLAND	-0.5759	-2.68	-0.3829	-2.32	-1.3715	-3.58	-0.9285	-5.38
PERRY	-	-	0.1136	0.45	-	-	-2.8102	-9.98
PHILADELPHIA	-	-	-	-	0.147	0.5	0.591	3.32
PIKE	-0.3639	-1.09	-0.3546	-1.36	-	-	-	-
POTTER	-	-	-0.3172	-0.91	-	-	-	-
SCHUYLKILL	-0.3264	-2.23	0.0802	0.72	-	-	-1.4643	-12.41
SNYDER	-	-	-0.4229	-1.57	-1.234	-2.29	-1.0672	-3.66
SOMERSET	-0.0209	-0.09	0.0261	0.15	-0.9	-2.25	-1.6387	-8.32
SULLIVAN	-	-	-0.7708	-1.65	-	-	-	-
SUSQUEHANNA	-0.1217	-0.36	-0.3085	-1.22	-	-	-	-
TIOGA	-	-	0.085	0.33	-	-	-	-
UNION	-0.2535	-0.75	-0.4117	-1.56	-	-	-1.5022	-5.38
VENANGO	-0.2131	-0.74	-0.4145	-1.91	-	-	-0.9508	-4.04
WARREN	-	-	-0.2137	-0.87	-	-	-1.4514	-5.37
WASHINGTON	-0.2056	-2.08	-0.19136	-2.52	0.2001	1.59	-0.15803	-2.01
WAYNE	-0.5082	-1.56	-0.2499	-1.04	-	-	-	-
WESTMORELAND	-0.25605	-7.79	-0.03601	-1.01	0.08757	1.14	0.33242	13.36
WYOMING	-	-	-0.2811	-0.93	-	-	-	-
YORK	-	-	-	-	-	-	-	-

Table C-11. Estimation Results of County Group Level OLS Base Model HH wo 2003 data

Dependent Var=LN(VMT)	Rural Interstates		Rural Non-Interstates		Urban Interstates		Urban Non-Interstates	
Adjusted R^2		99.20%		99.20%		99.80%		99.90%
N		390		594		378		486
	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
Constant	-57.073	-12.2	-9.788	-3.13	-40.418	-6.79	2.099	0.68
LN (Households)	1.3635	8.4	0.5913	4.44	1.007	4.11	0.6899	5.22
LN (Mean Household Income)	-0.3274	-1.97	-0.0837	-0.77	0.1162	0.58	-0.4529	-4.15
LN (Lane Miles Per Capita)	0.94707	35.53	0.05259	0.77	0.37407	3.9	-0.00233	-0.16
Year	0.036	10.94	0.0124	5.59	0.025089	6.29	0.007721	3.7
County Dummy								
ADAMS	-	-	0.3611	1.95	-	-	-1.8001	-8.85
ALLEGHENY	-	-	-2.7091	-11.92	0.2005	0.6	1.0015	5.74
ARMSTRONG	-	-	-0.0257	-0.13	-1.3089	-3.06	-1.0435	-4.88
BEAVER	-0.3783	-3.2	-0.8977	-7.65	-0.1469	-0.97	0.16876	1.86
BEDFORD	0.3142	0.97	0.3272	1.34	-	-	-	-
BERKS	-0.30866	-7.72	0.03192	1.07	-0.29576	-5.14	0.05021	2.06
BLAIR	-0.6748	-3.96	-0.4058	-2.74	-0.4886	-1.93	-0.2591	-1.9
BRADFORD	-	-	-0.0055	-0.03	-1.264	-2.85	-2.0597	-8.61
BUCKS	-0.03031	-0.32	-0.37386	-4.47	0.2352	2.03	0.81869	13.1
BUTLER	-0.0924	-0.69	0.1342	1.3	-0.4419	-2.24	-0.4245	-3.83
CAMBRIA	-	-	-0.0195	-0.17	-0.847	-3.53	-0.5503	-4.78
CAMERON	-	-	-0.5491	-1.09	-	-	-	-
CARBON	0.0202	0.07	-0.175	-0.75	-1.0166	-2.16	-1.5093	-6.25
CENTRE	-0.1182	-0.66	0.0887	0.63	-0.8899	-3.19	-0.3597	-2.45
CHESTER	0.14	1.38	0.08433	1.22	0.3092	2.55	0.68215	10.5
CLARION	0.407	1.15	-0.1017	-0.38	-	-	-1.8562	-6.27
CLEARFIELD	0.0217	0.09	0.1099	0.6	-1.6163	-3.53	-1.185	-5.96
CLINTON	0.152	0.41	-0.0436	-0.15	-0.8789	-1.61	-1.4176	-4.68
COLUMBIA	0.3108	1.09	-0.4973	-2.28	-0.585	-1.29	-0.5864	-2.53
CRAWFORD	-0.3139	-1.35	-0.0241	-0.14	-1.9636	-4.29	-1.1241	-5.88
CUMBERLAND	0.0962	0.94	-0.51554	-5.29	0.5348	3.96	0.18816	2.3
DAUPHIN	0.06801	0.95	-0.50875	-5.89	0.66538	6.93	0.47468	8.9
DELAWARE	-	-	-3.0909	-10.98	0.41925	4.5	0.71288	12.78
ELK	-	-	0.009	0.03	-	-	-1.5028	-4.87
ERIE	-0.42996	-6.57	-0.309	-5.56	-0.7426	-4.51	0.0478	1.03
FAYETTE	-	-	-0.0018	-0.02	-0.9601	-4.2	-0.9124	-7.62
FOREST	-	-	0.0928	0.18	-	-	-	-
FRANKLIN	0.1679	0.97	0.0267	0.2	-0.5157	-1.71	-0.7219	-5.04
FULTON	0.5205	1	-0.1041	-0.26	-	-	-	-
GREENE	0.2636	0.72	-0.211	-0.77	-	-	-	-
HUNTINGDON	0.0768	0.22	0.1896	0.71	-	-	-1.9934	-6.91
INDIANA	-	-	0.2659	1.49	-1.7429	-4.59	-1.3537	-6.92
JEFFERSON	0.1967	0.59	-0.1019	-0.4	-	-	-1.9885	-7.21
JUNIATA	-	-	0.1149	0.33	-	-	-	-
LACKAWANNA	-0.48404	-5.35	-0.8812	-8.03	0.1871	1.57	-0.06855	-0.96
LANCASTER	-0.35541	-8.46	0.23337	6.94	-0.04189	-0.79	0.11689	3.88
LAWRENCE	-0.2254	-1.02	-0.2971	-1.66	-0.8366	-2.56	-0.7629	-4.27
LEBANON	0.1979	1.06	-0.1543	-1	-	-	-0.7132	-4.62
LEHIGH	-0.11542	-2.41	-0.67639	-9.47	0.35947	5.98	0.41594	11.34
LUZERNE	-0.54666	-10.75	-0.52631	-10.34	0.00128	0.03	0.13556	4.67

LYCOMING	-0.5136	-2.75	-0.0683	-0.49	-0.0131	-0.05	-0.4878	-3.28
MCKEAN	-	-	-0.0541	-0.21	-1.2333	-2.42	-2.1039	-7.58
MERCER	-0.2456	-1.32	-0.2366	-1.66	-0.966	-3.27	-0.5167	-3.47
MIFFLIN	-	-	-0.2817	-1.07	-0.538	-1.1	-1.1406	-4.19
MONROE	0.1061	0.58	0.3112	2.17	-0.2475	-0.75	-1.4809	-9.56
MONTGOMERY	-0.0867	-0.62	-0.9952	-7.25	0.5466	2.91	1.08458	10.96
MONTOUR	0.8713	1.79	-0.6266	-1.64	-	-	-0.8528	-2.11
NORTHAMPTON	-	-	-0.34355	-4.22	0.18795	1.97	0.01697	0.31
NORTHUMBERLAND	-0.4186	-1.95	-0.2588	-1.55	-1.3815	-3.54	-0.7623	-4.4
PERRY	-	-	0.3821	1.43	-	-	-2.4131	-8.14
PHILADELPHIA	-	-	-	-	0.0871	0.27	0.3355	1.79
PIKE	0.071	0.2	-0.0839	-0.3	-	-	-	-
POTTER	-	-	0.0356	0.1	-	-	-	-
SCHUYLKILL	-0.2303	-1.57	0.1593	1.42	-	-	-1.362	-11.52
SNYDER	-	-	-0.098	-0.33	-1.0815	-1.8	-0.5954	-1.88
SOMERSET	0.2476	0.99	0.1933	1.02	-0.8591	-2.03	-1.3904	-6.79
SULLIVAN	-	-	-0.325	-0.66	-	-	-	-
SUSQUEHANNA	0.2919	0.83	-0.0611	-0.23	-	-	-	-
TIOGA	-	-	0.338	1.25	-	-	-	-
UNION	0.4679	1.21	-0.0185	-0.06	-	-	-0.9592	-2.99
VENANGO	0.1326	0.45	-0.2012	-0.88	-	-	-0.6421	-2.62
WARREN	-	-	0.0139	0.05	-	-	-1.1197	-4.02
WASHINGTON	-0.12322	-1.24	-0.13396	-1.75	0.2079	1.59	-0.07906	-1
WAYNE	-0.1028	-0.3	-0.0039	-0.02	-	-	-	-
WESTMORELAND	-0.31988	-9.37	-0.05638	-1.6	0.06052	0.74	0.29154	11.15
WYOMING	-	-	0.0394	0.12	-	-	-	-
YORK	-	-	-	-	-	-	-	-

Table C-12. Estimation Results of County Group Level OLS Base Model HH JrSr wo 2003 data

Dependent Var=LN(VMT)	Rural Interstates		Rural Non-Interstates		Urban Interstates		Urban Non-Interstates	
Adjusted R^2		99.20%		99.30%		99.80%		99.90%
N		390		594		378		486
	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
Constant	-71.66	-10.07	-3.282	-0.71	-33.103	-4.14	-7.333	-1.69
LN (Households)	1.2526	7.28	0.4871	3.57	1.1867	4.65	0.3623	2.6
Pop17 (% of Pop<17 yrs)	2.674	2.59	-0.3548	-0.58	-1.798	-1.66	2.5967	4.1
Pop65+ (% of Pop>65+ yrs)	-0.6	-0.4	4.5037	4.54	-4.126	-2.24	5.0622	5.13
LN (Mean Household Income)	-0.4389	-2.59	0.0284	0.26	0.1402	0.68	-0.441	-3.96
LN (Lane Miles Per Capita)	0.94019	35.41	0.05787	0.86	0.34394	3.55	-0.0201	-1.34
Year	0.04426	9.88	0.008897	3.05	0.020603	4.03	0.013622	4.99
County Dummy								
ADAMS	-	-	0.1916	0.99	-	-	-2.3464	-10.81
ALLEGHENY	-	-	-2.7852	-12.16	0.1137	0.32	1.2749	7.14
ARMSTRONG	-	-	-0.3918	-1.8	-0.8713	-1.9	-1.7743	-7.33
BEAVER	-0.3974	-2.6	-1.1795	-8.9	0.1738	0.87	-0.2499	-2.16
BEDFORD	0.1143	0.32	0.0072	0.03	-	-	-	-
BERKS	-0.28895	-5.88	-0.05887	-1.68	-0.22824	-3.55	-0.05466	-1.73
BLAIR	-0.7427	-3.74	-0.6777	-4.19	-0.1545	-0.54	-0.7644	-4.84
BRADFORD	-	-	-0.2593	-1.1	-0.8348	-1.75	-2.7981	-10.64
BUCKS	0.00519	0.05	-0.30959	-3.63	0.1318	1.07	0.97923	14.79
BUTLER	-0.1725	-1.19	0.011	0.1	-0.2574	-1.23	-0.7365	-6.16
CAMBRIA	-	-	-0.3803	-2.7	-0.4924	-1.77	-1.0773	-7.33
CAMERON	-	-	-1.2546	-2.33	-	-	-	-
CARBON	-0.0956	-0.29	-0.5909	-2.32	-0.5272	-1.04	-2.3208	-8.51
CENTRE	-0.0922	-0.52	0.108	0.78	-0.945	-3.39	-0.3941	-2.77
CHESTER	0.159	1.54	0.11101	1.6	0.2483	2.01	0.75124	11.73
CLARION	0.2191	0.58	-0.3837	-1.37	-	-	-2.6152	-8.34
CLEARFIELD	-0.1051	-0.39	-0.1864	-0.93	-1.2659	-2.65	-1.8273	-8.26
CLINTON	-0.0428	-0.11	-0.4197	-1.41	-0.3466	-0.6	-2.2963	-6.99
COLUMBIA	0.2001	0.66	-0.7893	-3.46	-0.2286	-0.48	-1.2107	-4.87
CRAWFORD	-0.4883	-1.88	-0.2498	-1.31	-1.657	-3.49	-1.7218	-8.17
CUMBERLAND	0.1282	1.18	-0.65266	-6.55	0.6699	4.54	0.00288	0.03
DAUPHIN	0.04659	0.61	-0.59057	-6.8	0.7833	7.32	0.32895	5.71
DELAWARE	-	-	-3.1686	-11.44	0.439	4.26	0.71113	12.32
ELK	-	-	-0.3945	-1.28	-	-	-2.451	-7.23
ERIE	-0.48465	-6.43	-0.37484	-6.25	-0.6591	-3.89	-0.12917	-2.38
FAYETTE	-	-	-0.2932	-2.17	-0.6228	-2.36	-1.4153	-9.74
FOREST	-	-	-0.6433	-1.15	-	-	-	-
FRANKLIN	0.0777	0.4	-0.1832	-1.26	-0.2578	-0.81	-1.1831	-7.42
FULTON	0.1528	0.27	-0.4673	-1.13	-	-	-	-
GREENE	0.0456	0.12	-0.5163	-1.79	-	-	-	-
HUNTINGDON	-0.1417	-0.38	-0.0594	-0.22	-	-	-2.7196	-8.93
INDIANA	-	-	0.0589	0.32	-1.4739	-3.75	-1.858	-8.95
JEFFERSON	-0.0073	-0.02	-0.4979	-1.81	-	-	-2.8928	-9.4
JUNIATA	-	-	-0.236	-0.64	-	-	-	-
LACKAWANNA	-0.4403	-3.14	-1.2112	-9.36	0.5197	2.77	-0.4829	-4.59
LANCASTER	-0.38636	-8.79	0.22754	6.67	-0.02164	-0.4	0.08061	2.68
LAWRENCE	-0.3257	-1.22	-0.6921	-3.4	-0.3572	-0.95	-1.4753	-6.94
LEBANON	0.1069	0.51	-0.3984	-2.4	-	-	-1.2225	-7.07

LEHIGH	-0.08677	-1.34	-0.8197	-10.76	0.48768	5.78	0.25015	5.08
LUZERNE	-0.4375	-4.01	-0.82383	-10.39	0.2328	1.85	-0.13494	-2
LYCOMING	-0.6402	-3.06	-0.2766	-1.82	0.3024	1.06	-0.9682	-5.86
MCKEAN	-	-	-0.4065	-1.48	-0.7321	-1.34	-2.9504	-9.69
MERCER	-0.3227	-1.47	-0.5491	-3.39	-0.5969	-1.82	-1.0897	-6.23
MIFFLIN	-	-	-0.6176	-2.2	-0.0113	-0.02	-1.9931	-6.64
MONROE	-0.0743	-0.38	0.2545	1.71	-0.0811	-0.24	-1.8664	-11.4
MONTGOMERY	0.0595	0.4	-1.06	-7.6	0.4833	2.38	1.2311	11.92
MONTOUR	0.5901	1.12	-1.1181	-2.78	-	-	-2.0211	-4.6
NORTHAMPTON	-	-	-0.48913	-5.68	0.3332	2.97	-0.1902	-2.9
NORTHUMBERLAND	-0.4887	-1.92	-0.6394	-3.37	-0.9801	-2.34	-1.4226	-6.98
PERRY	-	-	0.2291	0.83	-	-	-3.1246	-10.06
PHILADELPHIA	-	-	-	-	-0.1274	-0.38	0.714	3.72
PIKE	-0.2211	-0.58	-0.3503	-1.2	-	-	-	-
POTTER	-	-	-0.4017	-1.02	-	-	-	-
SCHUYLKILL	-0.2091	-1.09	-0.2218	-1.59	-	-	-1.9032	-12.5
SNYDER	-	-	-0.3663	-1.2	-0.6535	-1.05	-1.3945	-4.17
SOMERSET	0.1317	0.46	-0.1608	-0.77	-0.4415	-0.98	-2.0951	-9.02
SULLIVAN	-	-	-1.0856	-2.06	-	-	-	-
SUSQUEHANNA	0.0166	0.04	-0.3597	-1.27	-	-	-	-
TIOGA	-	-	0.0274	0.1	-	-	-	-
UNION	0.3071	0.77	-0.2624	-0.85	-	-	-1.6396	-4.96
VENANGO	-0.0591	-0.18	-0.5284	-2.16	-	-	-1.4086	-5.21
WARREN	-	-	-0.3359	-1.22	-	-	-1.9684	-6.44
WASHINGTON	-0.0895	-0.68	-0.41314	-4.26	0.482	2.74	-0.4355	-4.25
WAYNE	-0.3183	-0.84	-0.3809	-1.38	-	-	-	-
WESTMORELAND	-0.22539	-2.89	-0.27376	-4.86	0.2334	1.84	0.13148	2.72
WYOMING	-	-	-0.2079	-0.62	-	-	-	-
YORK	-	-	-	-	-	-	-	-

Table C-13. Estimation Results of County Group Level OLS Base Model HH wo 2003 data

Dependent Var=LN(VMT)	**Rural Interstates**		**Rural Non-Interstates**		**Urban Interstates**		**Urban Non-Interstates**	
Adjusted R^2	**98.90%**		**99.50%**		**99.90%**		**100%**	
N	**99**		**117**		**108**		**117**	
	Coefficient	**T-stat**	**Coefficient**	**T-stat**	**Coefficient**	**T-stat**	**Coefficient**	**T-stat**
Constant	-8.481	-3.65	5.416	2.39	0.096	0.03	13.544	11.86
LN (Households)	1.7306	6.53	0.9829	2.85	0.9961	2.41	0.5246	3.45
LN (Mean Household Income)	1.4781	8.84	0.503	4.51	1.1029	4.77	0.01153	0.14
LN (Lane Miles Per Capita)	1.01902	22.04	0.3205	1.03	0.5246	2.6	0.02811	0.98
County Group Dummy								
ALTGR	-0.7897	-2.48	0.0966	0.33	-0.482	-0.58	0.7485	3.95
CNTRGR	-0.691	-2.84	0.055	0.28	-0.2953	-0.34	0.8136	5.53
EPAGR	-1.5561	-3.26	-0.4572	-1.52	0.0875	0.18	1.6103	5.6
HARRGR	-1.6961	-2.76	-0.2265	-0.46	0.1676	0.64	1.7624	4.81
I81GR	-1.305	-2.98	-0.3829	-1.24	0.0434	0.08	1.2709	4.82
NCNTGR	-	-	0.22787	2.28	-1.635	-1.17	-0.37804	-23.67
NEPAGR	-0.30627	-3.23	0.24566	2.85	-0.187	-0.14	-0.878	-19.47
NTIERGR	-	-	0.2161	2.37	-1.212	-0.84	-1.51292	-23.95
PHILY	-2.3131	-2.87	-1.3242	-2.65	0.13327	1.37	2.4131	5.04
SEDA-COG	-0.5169	-2.52	0.0476	0.3	-0.708	-0.69	0.7359	5.9
SHVGR	-1.0282	-3.31	-0.3475	-1.64	-0.6132	-0.68	1.1193	5.9
SWPAC	-2.3276	-3.11	-0.7299	-1.2	-	-	2.2381	4.95
WPAGR	-	-	-	-	-	-	-	-

Table C-14. Estimation Results of County-Level OLS Base Model HH for VMT per LM

Dependent Var=LN(VMTPLM)	Rural Interstates		Rural Non-Interstates		Urban Interstates		Urban Non-Interstates	
Adjusted R^2		94.10%		93.10%		96.60%		67.90%
N		434		660		421		544
	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
Constant	-61.879	-15.1	-0.286	-0.06	-30.277	-4.73	15.687	1.78
LN (Households)	0.3889	2.72	0.1525	0.8	0.9037	3.79	1.9625	5.26
LN (Mean Household Income)	-0.2795	-1.77	0.0988	0.54	0.2644	1.13	-0.5474	-1.61
Year	0.037728	12.8	0.004824	1.39	0.015866	3.64	-0.009898	-1.63
County Dummy								
ADAMS	-	-	0.4718	1.64	-	-	2.8278	5.06
ALLEGHENY	-	-	-0.0828	-0.33	-1.1557	-3.72	-2.3994	-4.94
ARMSTRONG	-	-	-0.1631	-0.52	0.6529	1.7	3.0778	5.12
BEAVER	-0.2988	-2.85	0.0741	0.52	0.0721	0.42	1.0667	4.01
BEDFORD	0.2555	0.88	0.0284	0.07	-	-	-	-
BERKS	-0.36	-10.95	0.11875	2.42	-0.04731	-1.02	0.21523	2.78
BLAIR	-0.6914	-4.49	0.438	2.14	0.4779	1.91	1.8293	4.69
BRADFORD	-	-	-0.537	-1.55	0.4629	1.09	2.9603	4.45
BUCKS	-0.00685	-0.08	0.3796	3.65	-0.3047	-2.54	-0.4054	-2.22
BUTLER	-0.137	-1.14	0.1749	1.07	0.19	0.95	1.5961	5.1
CAMBRIA	-	-	0.3797	2.16	0.2972	1.41	1.3458	4.08
CAMERON	-	-	-0.0247	-0.03	-	-	-	-
CARBON	0.0171	0.07	0.5583	1.59	1.0272	2.37	3.2438	4.79
CENTRE	-0.2222	-1.39	0.341	1.59	0.1636	0.62	2.2978	5.56
CHESTER	0.11544	1.21	0.2441	2.14	-0.1245	-0.89	0.3454	1.68
CLARION	0.3483	1.09	-0.2462	-0.58	-	-	4.4347	5.4
CLEARFIELD	-0.0113	-0.05	-0.0628	-0.21	0.8041	2.25	2.5952	4.65
CLINTON	0.1085	0.33	0.102	0.23	1.0536	1.93	4.2367	4.98
COLUMBIA	0.3028	1.18	-0.3505	-1.03	1.3551	3.22	3.3366	5.08
CRAWFORD	-0.3452	-1.64	-0.352	-1.25	0.4859	1.41	2.535	4.72
CUMBERLAND	0.03511	0.39	0.1954	1.59	0.5061	3.36	1.1462	4.83
DAUPHIN	0.17015	2.74	0.45216	5.28	0.4988	4.96	0.8893	5.56
DELAWARE	-	-	0.7214	7.79	0.1768	1.68	-0.335	-2.07
ELK	-	-	0.3185	0.71	-	-	3.7367	4.27
ERIE	-0.5069	-9.05	0.02394	0.31	0.23854	2.74	0.5815	4.2
FAYETTE	-	-	0.0911	0.5	0.0016	0.01	1.2966	3.81
FOREST	-	-	0.0336	0.04	-	-	-	-
FRANKLIN	0.1365	0.88	0.2482	1.19	0.9305	3.64	2.1369	5.33
FULTON	0.4331	0.93	-0.0131	-0.02	-	-	-	-
GREENE	0.1612	0.49	-0.4529	-1.04	-	-	4.9785	5.78
HUNTINGDON	0.1159	0.37	0.0585	0.14	-	-	3.9684	4.95
INDIANA	-	-	0.0446	0.16	-0.1185	-0.34	2.7944	5.14
JEFFERSON	0.1901	0.64	-0.1747	-0.44	-	-	3.6407	4.73
JUNIATA	-	-	0.2896	0.53	-	-	-	-
LACKAWANNA	-0.46861	-5.7	0.231	2.06	0.1794	1.36	0.8112	3.89
LANCASTER	-0.40586	-10.32	0.26222	4.63	-0.02244	-0.39	-0.17182	-1.85
LAWRENCE	-0.2082	-1.04	0.3183	1.2	0.3613	1.11	2.0382	4
LEBANON	0.1723	1.03	0.4628	2.05	-	-	2.1152	4.86
LEHIGH	-0.10535	-2.33	0.1167	1.84	0.33396	4.77	0.7128	6.35
LUZERNE	-0.54426	-13.59	0.03919	0.69	0.1212	2.12	0.123	1.35
LYCOMING	-0.4644	-2.79	-0.1105	-0.5	0.7694	2.83	1.9104	4.5

MCKEAN	-	-	0.1104	0.27	0.7032	1.41	3.451	4.44
MERCER	-0.294	-1.76	-0.1036	-0.46	0.3328	1.22	1.8281	4.3
MIFFLIN	-	-	0.3956	0.99	1.194	2.43	3.8741	5.05
MONROE	0.0001	0	0.5258	2.41	1.3041	4.86	2.1665	5.15
MONTGOMERY	-0.0315	-0.25	0.4014	2.53	-0.2838	-1.51	-0.7943	-2.79
MONTOUR	0.8311	1.9	0.1022	0.17	-	-	6.143	5.36
NORTHAMPTON	-	-	0.38999	4.5	0.4187	4.14	0.627	3.9
NORTHUMBERLAND	-0.3524	-1.82	0.0929	0.36	0.5626	1.78	2.2414	4.55
PERRY	-	-	0.4291	1.02	-	-	4.5585	5.61
PHILADELPHIA	-	-	-	-	-0.6798	-2	-2.4855	-4.66
PIKE	-0.0154	-0.05	0.581	1.4	-	-	-	-
POTTER	-	-	-0.3966	-0.68	-	-	-	-
SCHUYLKILL	-0.2317	-1.75	0.3442	1.95	-	-	1.1522	3.47
SNYDER	-	-	0.1664	0.36	1.1961	2.1	4.9216	5.5
SOMERSET	0.2206	0.98	-0.1194	-0.4	1.1399	3.1	2.6248	4.57
SULLIVAN	-	-	-0.3902	-0.51	-	-	-	-
SUSQUEHANNA	0.2481	0.79	-0.5032	-1.2	1.5381	2.92	4.3319	5.24
TIOGA	-	-	-0.1214	-0.28	-	-	-	-
UNION	0.2328	0.67	0.4657	1.01	-	-	4.8746	5.42
VENANGO	0.1399	0.52	-0.1252	-0.35	-	-	3.5264	5.07
WARREN	-	-	-0.058	-0.14	-	-	4.037	5.14
WASHINGTON	-0.13801	-1.54	-0.0456	-0.37	0.332	2.26	0.8157	3.52
WAYNE	-0.0893	-0.3	-0.1495	-0.37	-	-	4.2094	5.44
WESTMORELAND	-0.26705	-8.13	0.2812	5.75	-0.35681	-7.72	-0.30446	-3.96
WYOMING	-	-	0.2718	0.54	-	-	4.9149	4.98
YORK	-	-	-	-	-	-	-	-

Appendix D. VMT Growth Rate Forecasts

Table D-1. Forecasted Growth Rates Based on County-Level OLS Base Model HH

HH Model	Rates between 2003 - 2010				Rates between 2010 - 2020				Rates between 2020 - 2030			
COUNTY	CAT A	CAT B	CAT C	CAT D	CAT A	CAT B	CAT C	CAT D	CAT A	CAT B	CAT C	CAT D
ADAMS	0	0.52	0	2.66	0	0.26	0	2.19	0	-0.1	0	1.51
ALLEGHENY	0	0.39	2.6	0.05	0	0.16	2.46	-0.34	0	-0.19	2.22	-0.94
ARMSTRONG	0	0.42	2.8	0.83	0	0.19	2.67	0.41	0	-0.1	2.47	-0.07
BEAVER	3.45	0.41	2.82	0.76	3.13	0.18	2.68	0.39	2.69	-0.16	2.45	-0.18
BEDFORD	3.44	0.59	0	0	3.17	0.3	0	0	2.85	-0.04	0	0
BERKS	3.72	0.4	3.17	1.87	3.38	0.16	3	1.42	2.93	-0.19	2.73	0.8
BLAIR	3.22	0.22	2.45	0.1	2.89	-0.04	2.3	-0.28	2.39	-0.46	2	-0.91
BRADFORD	0	0.59	2.99	1.15	0	0.35	2.84	0.82	0	0.04	2.64	0.37
BUCKS	4.23	0.72	3.64	3.02	3.89	0.46	3.42	2.51	3.49	0.14	3.16	1.93
BUTLER	3.99	0.57	3.56	2.71	3.68	0.31	3.34	2.27	3.25	-0.06	3.03	1.67
CAMBRIA	0	0.15	2.16	-0.52	0	-0.12	1.98	-0.96	0	-0.71	1.53	-1.85
CAMERON	0	0.16	0	0	0	-0.08	0	0	0	-0.46	0	0
CARBON	3.56	0.45	3.07	1.32	3.21	0.22	2.92	0.85	2.82	-0.07	2.72	0.31
CENTRE	3.88	0.62	3.44	2.19	3.57	0.39	3.25	1.74	3	-0.07	2.88	0.94
CHESTER	4.24	0.74	3.84	3.33	3.87	0.47	3.59	2.71	3.41	0.12	3.26	2
CLARION	3.71	0.66	0	1.15	3.41	0.39	0	0.84	3	0.04	0	0.35
CLEARFIELD	3.53	0.51	3.07	1.12	3.24	0.27	2.91	0.79	2.8	-0.12	2.63	0.24
CLINTON	3.51	0.3	2.7	0.92	3.12	0.13	2.62	0.36	2.64	-0.23	2.37	-0.28
COLUMBIA	3.72	0.42	3.06	1.66	3.39	0.21	2.92	1.22	2.9	-0.16	2.65	0.57
CRAWFORD	3.32	0.32	2.72	0.54	3.04	0.06	2.56	0.24	2.56	-0.36	2.27	-0.32
CUMBERLAND	4.33	0.6	3.8	3.73	3.93	0.36	3.56	3	3.34	-0.04	3.18	2.03
DAUPHIN	3.52	0.39	3.03	1.28	3.21	0.14	2.85	0.88	2.74	-0.23	2.58	0.25
DELAWARE	0	0.46	2.9	1.1	0	0.24	2.76	0.72	0	-0.12	2.51	0.11
ELK	0	0.58	0	0.24	0	0.3	0	-0.04	0	-0.02	0	-0.42
ERIE	3.39	0.35	2.79	0.72	3.09	0.11	2.64	0.38	2.59	-0.32	2.34	-0.25
FAYETTE	0	0.43	2.79	0.68	0	0.18	2.64	0.28	0	-0.21	2.37	-0.34
FOREST	0	0.38	0	0	0	0.22	0	0	0	-0.12	0	0
FRANKLIN	4.14	0.72	3.37	2.4	3.82	0.46	3.2	2.01	3.41	0.13	2.97	1.47
FULTON	3.94	0.72	0	0	3.64	0.4	0	0	3.3	0.06	0	0
GREENE	3.47	0.46	0	0.78	3.19	0.2	0	0.5	2.63	-0.28	0	-0.2
HUNTINGDON	3.4	0.46	0	0.77	3.16	0.21	0	0.55	2.55	-0.35	0	-0.21
INDIANA	0	0.57	2.99	0.97	0	0.34	2.86	0.64	0	-0.03	2.61	0.08
JEFFERSON	3.42	0.4	0	0.57	3.11	0.15	0	0.23	2.72	-0.17	0	-0.24
JUNIATA	0	0.39	0	0	0	0.15	0	0	0	-0.15	0	0
LACKAWANNA	3.31	0.31	2.54	0.23	3	0.08	2.4	-0.12	2.57	-0.27	2.16	-0.66
LANCASTER	4.1	0.63	3.51	2.71	3.75	0.39	3.31	2.2	3.31	0.06	3.05	1.56
LAWRENCE	3.51	0.37	2.76	0.85	3.17	0.17	2.64	0.41	2.72	-0.13	2.45	-0.19
LEBANON	3.75	0.44	0	1.74	3.44	0.2	0	1.34	2.97	-0.15	0	0.7
LEHIGH	3.68	0.4	3.17	1.81	3.33	0.17	3.01	1.31	2.86	-0.17	2.74	0.64
LUZERNE	3.3	0.28	2.56	0.31	2.99	0.04	2.42	-0.05	2.52	-0.34	2.16	-0.63
LYCOMING	3.4	0.4	2.78	0.62	3.1	0.14	2.63	0.3	2.67	-0.22	2.38	-0.23
MCKEAN	0	0.47	2.82	0.61	0	0.21	2.66	0.37	0	-0.22	2.35	-0.18
MERCER	3.44	0.35	2.69	0.67	3.14	0.12	2.56	0.31	2.65	-0.27	2.28	-0.31
MIFFLIN	0	0.32	2.69	0.51	0	0.08	2.54	0.17	0	-0.24	2.34	-0.3
MONROE	4.44	0.58	4.1	4.46	3.97	0.3	3.74	3.51	3.48	-0.03	3.36	2.59
MONTGOMERY	3.79	0.49	3.19	1.87	3.48	0.25	3.01	1.46	3.05	-0.09	2.76	0.9
MONTOUR	3.52	0.68	0	0.98	3.26	0.38	0	0.73	2.83	0	0	0.23
NORTHAMPTON	0	0.39	3.26	2.36	0	0.17	3.08	1.83	0	-0.17	2.82	1.12
NORTHUMBERLAND	3.29	0.34	2.58	0.2	2.99	0.1	2.44	-0.14	2.55	-0.24	2.21	-0.69
PERRY	0	0.47	0	3.16	0	0.21	0	2.56	0	-0.09	0	1.91
PHILADELPHIA	0	0	2.45	-0.08	0	0	2.31	-0.54	0	0	2.04	-1.22
PIKE	4.67	0.59	0	0	4.07	0.33	0	0	3.5	0.04	0	0
POTTER	0	0.55	0	0	0	0.27	0	0	0	-0.02	0	0
SCHUYLKILL	3.57	0.51	0	0.66	3.26	0.28	0	0.28	2.76	-0.12	0	-0.35
SNYDER	0	0.45	3.1	1.54	0	0.21	2.94	1.22	0	-0.23	2.62	0.66
SOMERSET	3.46	0.43	2.79	0.69	3.18	0.18	2.64	0.4	2.72	-0.24	2.34	-0.15
SULLIVAN	0	0.4	0	0	0	0.19	0	0	0	-0.21	0	0
SUSQUEHANNA	3.84	0.58	3.22	1.84	3.53	0.31	3.04	1.48	3.18	0	2.83	1.07
TIOGA	0	0.67	0	0	0	0.38	0	0	0	0	0	0
UNION	4.21	0.7	0	3.03	3.84	0.45	0	2.47	2.97	-0.26	0	1.2
VENANGO	3.37	0.45	0	0.29	3.09	0.2	0	0.01	2.69	-0.15	0	-0.47
WARREN	0	0.47	0	0.54	0	0.22	0	0.2	0	-0.09	0	-0.24
WASHINGTON	3.49	0.48	2.9	0.83	3.18	0.26	2.76	0.45	2.77	-0.05	2.56	-0.06
WAYNE	4.04	0.5	0	2.92	3.66	0.27	0	2.3	3.17	-0.08	0	1.54
WESTMORELAND	3.43	0.47	2.85	0.67	3.14	0.23	2.71	0.32	2.72	-0.1	2.48	-0.18
WYOMING	0	0.34	0	1.13	0	0.11	0	0.65	0	-0.18	0	0.1
YORK	3.78	0.43	3.23	2.04	3.44	0.18	3.05	1.56	2.98	-0.17	2.78	0.93

Table D-2. Forecasted Growth Rates Based on County-Level OLS Base Model POP

POP MODEL	Rates between 2003 - 2010				Rates between 2010 - 2020				Rates between 2020 - 2030			
COUNTY	CAT A	CAT B	CAT C	CAT D	CAT A	CAT B	CAT C	CAT D	CAT A	CAT B	CAT C	CAT D
ADAMS	0	0.4	0	3.01	0	0.38	0	3.05	0	0.38	0	3.06
ALLEGHENY	0	0.69	2.77	0.56	0	0.71	2.85	0.66	0	0.73	2.93	0.76
ARMSTRONG	0	0.56	2.9	1.22	0	0.58	2.99	1.33	0	0.59	3.07	1.45
BEAVER	3.7	0.6	2.97	1.22	3.72	0.61	3.04	1.36	3.73	0.62	3.13	1.48
BEDFORD	3.67	0.76	0	0	3.71	0.69	0	0	3.75	0.61	0	0
BERKS	3.86	0.45	3.32	2.37	3.87	0.46	3.37	2.45	3.88	0.46	3.41	2.52
BLAIR	3.64	0.57	2.69	0.76	3.66	0.57	2.77	0.91	3.68	0.57	2.84	1.07
BRADFORD	0	0.59	2.98	1.28	0	0.58	3.04	1.45	0	0.56	3.11	1.62
BUCKS	3.94	0.41	3.55	2.96	3.95	0.4	3.55	2.99	3.95	0.39	3.55	3.02
BUTLER	3.95	0.44	3.62	3.02	3.96	0.41	3.61	3.09	3.97	0.38	3.6	3.17
CAMBRIA	0	0.61	2.42	0.13	0	0.61	2.48	0.24	0	0.61	2.55	0.35
CAMERON	0	0.7	0	0	0	0.69	0	0	0	0.66	0	0
CARBON	3.78	0.57	3.22	1.82	3.79	0.6	3.3	1.87	3.79	0.62	3.36	1.94
CENTRE	3.87	0.51	3.46	2.47	3.88	0.51	3.48	2.51	3.88	0.51	3.5	2.55
CHESTER	3.99	0.43	3.79	3.38	3.98	0.44	3.77	3.3	3.98	0.44	3.73	3.25
CLARION	3.7	0.62	0	1.23	3.73	0.58	0	1.46	3.76	0.56	0	1.64
CLEARFIELD	3.74	0.66	3.21	1.53	3.76	0.63	3.25	1.69	3.78	0.61	3.3	1.85
CLINTON	3.74	0.45	2.85	1.43	3.73	0.56	2.99	1.4	3.73	0.59	3.07	1.46
COLUMBIA	3.83	0.44	3.16	2.09	3.83	0.47	3.23	2.15	3.84	0.49	3.3	2.23
CRAWFORD	3.69	0.61	2.95	1.15	3.72	0.57	3	1.37	3.75	0.55	3.06	1.57
CUMBERLAND	4.07	0.26	3.79	3.9	4.04	0.31	3.77	3.7	4.02	0.37	3.76	3.51
DAUPHIN	3.78	0.56	3.22	1.84	3.8	0.55	3.26	1.97	3.81	0.56	3.32	2.05
DELAWARE	0	0.55	2.98	1.41	0	0.55	3.05	1.53	0	0.57	3.13	1.64
ELK	0	0.74	0	0.43	0	0.69	0	0.7	0	0.65	0	0.9
ERIE	3.71	0.59	2.99	1.28	3.73	0.59	3.05	1.44	3.75	0.58	3.12	1.61
FAYETTE	0	0.62	2.92	1.07	0	0.63	3	1.2	0	0.64	3.08	1.34
FOREST	0	0.64	0	0	0	0.64	0	0	0	0.6	0	0
FRANKLIN	3.84	0.44	3.23	2.23	3.87	0.42	3.28	2.39	3.88	0.43	3.34	2.5
FULTON	3.85	0.58	0	0	3.88	0.51	0	0	3.92	0.43	0	0
GREENE	3.69	0.64	0	1.16	3.72	0.6	0	1.4	3.75	0.59	0	1.56
HUNTINGDON	3.7	0.7	0	1.25	3.74	0.63	0	1.52	3.76	0.61	0	1.7
INDIANA	0	0.64	3.04	1.26	0	0.63	3.1	1.41	0	0.63	3.18	1.57
JEFFERSON	3.67	0.6	0	1.01	3.7	0.58	0	1.19	3.72	0.58	0	1.36
JUNIATA	0	0.32	0	0	0	0.36	0	0	0	0.39	0	0
LACKAWANNA	3.64	0.58	2.7	0.77	3.66	0.57	2.78	0.92	3.68	0.58	2.85	1.07
LANCASTER	3.92	0.42	3.48	2.81	3.92	0.42	3.5	2.83	3.93	0.43	3.53	2.85
LAWRENCE	3.72	0.52	2.88	1.3	3.72	0.56	2.98	1.35	3.72	0.61	3.08	1.41
LEBANON	3.83	0.45	0	2.11	3.84	0.45	0	2.22	3.85	0.47	0	2.27
LEHIGH	3.86	0.47	3.34	2.35	3.86	0.51	3.4	2.36	3.86	0.53	3.45	2.39
LUZERNE	3.66	0.57	2.76	0.91	3.68	0.57	2.83	1.06	3.7	0.57	2.91	1.21
LYCOMING	3.68	0.61	2.93	1.12	3.72	0.58	3	1.34	3.74	0.58	3.07	1.49
MCKEAN	0	0.66	2.94	0.98	0	0.6	2.98	1.24	0	0.56	3.03	1.45
MERCER	3.69	0.54	2.84	1.15	3.71	0.55	2.91	1.28	3.73	0.55	2.98	1.41
MIFFLIN	0	0.59	2.89	1.11	0	0.57	2.96	1.29	0	0.57	3.03	1.44
MONROE	4.19	0.21	4.15	4.79	4.14	0.25	4.02	4.41	4.1	0.27	3.92	4.12
MONTGOMERY	3.84	0.47	3.26	2.2	3.85	0.46	3.3	2.31	3.87	0.46	3.35	2.41
MONTOUR	3.7	0.77	0	1.29	3.74	0.69	0	1.57	3.77	0.65	0	1.77
NORTHAMPTON	0	0.34	3.37	2.83	0	0.37	3.42	2.81	0	0.41	3.47	2.8
NORTHUMBERLAND	3.64	0.62	2.75	0.74	3.66	0.61	2.82	0.91	3.67	0.62	2.9	1.03
PERRY	0	0.27	0	3.49	0	0.28	0	3.43	0	0.29	0	3.39
PHILADELPHIA	0	0	2.56	0.28	0	0	2.64	0.34	0	0	2.72	0.4
PIKE	4.34	0.11	0	0	4.22	0.25	0	0	4.13	0.35	0	0
POTTER	0	0.57	0	0	0	0.53	0	0	0	0.52	0	0
SCHUYLKILL	3.64	0.6	0	0.8	3.66	0.6	0	0.92	3.68	0.61	0	1.05
SNYDER	0	0.51	3.22	2	0	0.48	3.25	2.15	0	0.43	3.29	2.39
SOMERSET	3.68	0.61	2.91	1.07	3.71	0.58	2.97	1.28	3.74	0.55	3.03	1.49
SULLIVAN	0	0.45	0	0	0	0.46	0	0	0	0.47	0	0
SUSQUEHANNA	3.81	0.51	3.23	2.03	3.84	0.48	3.27	2.21	3.87	0.44	3.32	2.41
TIOGA	0	0.66	0	0	0	0.58	0	0	0	0.5	0	0
UNION	3.96	0.37	0	3.11	3.96	0.38	0	3.11	3.95	0.41	0	3.05
VENANGO	3.62	0.66	0	0.66	3.65	0.62	0	0.88	3.68	0.6	0	1.06
WARREN	0	0.58	0	0.81	0	0.57	0	1	0	0.55	0	1.18
WASHINGTON	3.7	0.62	3	1.22	3.71	0.63	3.07	1.34	3.73	0.65	3.16	1.46
WAYNE	3.99	0.35	0	3.3	3.97	0.39	0	3.2	3.96	0.41	0	3.14
WESTMORELAND	3.68	0.66	2.98	1.07	3.7	0.65	3.04	1.23	3.72	0.64	3.11	1.39
WYOMING	0	0.39	0	1.53	0	0.44	0	1.6	0	0.48	0	1.69
YORK	3.88	0.45	3.37	2.49	3.88	0.45	3.4	2.54	3.89	0.46	3.44	2.59

Table D-3. Forecasted Growth Rates Based on County-Level OLS Base Model HH JrSr

HH,Jr,Sr Model	Rates between 2003 - 2010				Rates between 2010 - 2020				Rates between 2020 - 2030			
COUNTY	CAT A	CAT B	CAT C	CAT D	CAT A	CAT B	CAT C	CAT D	CAT A	CAT B	CAT C	CAT D
ADAMS	0	1.15	0	2.42	0	2.86	0	1	0	3.14	0	0.06
ALLEGHENY	0	-1.51	2.78	0.61	0	2	0.67	-1.09	0	2.48	0.15	-0.69
ARMSTRONG	0	-0.51	2.98	1.14	0	3.27	0.65	-0.7	0	5.04	-0.47	-0.67
BEAVER	3.54	-0.52	2.96	1.05	3.85	2.85	0.78	-0.63	3.58	4.79	-0.45	-0.69
BEDFORD	3.68	2.63	0	0	3.92	2.87	0	0	3.56	3.99	0	0
BERKS	3.79	-0.96	3.56	2.17	4.09	0.83	1.88	0.87	3.67	1.17	1.32	0.04
BLAIR	3.63	-0.96	2.25	0.42	3.84	1.99	0.31	-1.1	3.15	1.91	0.09	-0.63
BRADFORD	0	2.54	2.23	0.59	0	4.03	0.61	-0.53	0	4.37	0.12	-0.42
BUCKS	4.19	1.55	3.42	2.57	4.48	3.54	1.63	1.17	4.29	3.69	0.95	0.16
BUTLER	4.13	0.95	3.3	2.35	4.34	3.3	1.5	0.95	4.05	3.94	0.66	0.03
CAMBRIA	0	-1.23	1.95	-0.07	0	3.12	-0.57	-2.07	0	3.38	-1.17	-1.13
CAMERON	0	-0.22	0	0	0	1.68	0	0	0	0.14	0	0
CARBON	3.31	-0.34	3.6	1.65	3.91	2.37	1.27	-0.07	3.62	3.99	0.27	-0.42
CENTRE	4.07	0.78	3.16	1.93	4.56	2	1.5	0.73	3.68	1.42	1.52	0.08
CHESTER	4.25	1.51	3.62	2.83	4.5	3.43	1.82	1.35	4.19	3.11	1.3	0.24
CLARION	3.8	0.76	0	1.08	4.2	2.84	0	-0.2	3.79	2.59	0	-0.24
CLEARFIELD	3.43	1.31	2.83	0.92	3.88	3.54	0.93	-0.42	3.58	4.85	-0.12	-0.54
CLINTON	3.8	-0.28	2.46	1.02	4.05	1.59	0.9	-0.38	3.47	2.31	0.36	-0.45
COLUMBIA	3.75	-0.09	3.16	1.76	4.37	2.27	0.98	0.17	3.69	1.78	0.97	-0.11
CRAWFORD	3.52	1	2.13	0.32	3.89	3.34	0.27	-0.99	3.29	2.34	0.33	-0.47
CUMBERLAND	4.47	0.79	3.65	3.32	4.77	2.91	1.7	1.64	4.2	2.1	1.42	0.33
DAUPHIN	3.66	-0.49	3.14	1.47	3.98	2.51	1.03	-0.13	3.49	1.8	0.89	-0.22
DELAWARE	0	-1.59	3.51	1.72	0	1.35	1.37	0.1	0	2.04	0.63	-0.29
ELK	0	1.13	0	0.25	0	4.44	0	-1.41	0	7.37	0	-1.02
ERIE	3.58	-0.1	2.62	0.83	3.88	2.74	0.68	-0.65	3.3	2.48	0.38	-0.45
FAYETTE	0	-0.29	2.71	0.87	0	3.32	0.49	-0.88	0	3.53	-0.04	-0.6
FOREST	0	5.01	0	0	0	1.3	0	0	0	0.11	0	0
FRANKLIN	4.56	0.51	2.94	2.15	4.68	1.57	1.75	1.21	4.11	1.65	1.55	0.25
FULTON	3.73	2.51	0	0	4.05	2.84	0	0	4.02	5.23	0	0
GREENE	3.41	-0.11	0	1.02	4.04	4.54	0	-1.06	3.38	2.97	0	-0.49
HUNTINGDON	3.62	1.52	0	0.39	4.1	2.72	0	-0.54	3.29	2.83	0	-0.49
INDIANA	0	1.23	2.53	0.74	0	3.96	0.45	-0.75	0	3.18	0.45	-0.4
JEFFERSON	3.57	0.54	0	0.54	3.91	2.78	0	-0.78	3.56	4.31	0	-0.65
JUNIATA	0	0.48	0	0	0	2	0	0	0	2.8	0	0
LACKAWANNA	3.44	-1.12	2.77	0.73	3.9	2.11	0.47	-0.95	3.4	2.89	-0.1	-0.64
LANCASTER	4.27	0.28	3.45	2.57	4.43	1.71	2.04	1.38	3.94	1.93	1.61	0.25
LAWRENCE	3.7	-0.93	2.9	1.22	4.03	3.12	0.46	-0.74	3.55	3.47	0.08	-0.54
LEBANON	3.98	0.88	0	1.46	4.17	2.59	0	0.29	3.68	2.88	0	-0.16
LEHIGH	3.77	-0.69	3.44	2.03	4.02	1.37	1.74	0.63	3.56	1.93	1.12	-0.09
LUZERNE	3.45	-0.77	2.63	0.68	3.8	2.22	0.55	-0.89	3.36	3.01	-0.18	-0.65
LYCOMING	3.45	-0.07	2.78	0.8	3.91	2.38	0.77	-0.61	3.43	3.03	0.2	-0.5
MCKEAN	0	0.29	3	0.81	0	2.64	0.76	-0.6	0	4.12	-0.34	-0.62
MERCER	3.62	-0.65	2.73	0.97	4.01	1.91	0.78	-0.49	3.52	2.71	0.07	-0.51
MIFFLIN	0	1.52	1.85	0.13	0	2.43	0.64	-0.76	0	3.52	-0.02	-0.58
MONROE	3.65	1.68	4.77	4.1	4.43	3.53	2.14	2.07	4.33	3.69	1.08	0.35
MONTGOMERY	3.94	-0.39	3.3	2	4.17	1.49	1.71	0.76	3.84	1.88	1.07	0
MONTOUR	3.15	0.46	0	1.2	3.94	3.06	0	-0.33	3.86	4.93	0	-0.58
NORTHAMPTON	0	0.38	3.33	2.28	0	3.17	1.14	0.55	0	3.61	0.47	-0.13
NORTHUMBERLAND	3.27	-0.17	2.65	0.49	3.74	2.33	0.61	-0.97	3.31	3.77	-0.26	-0.73
PERRY	0	1.77	0	2.64	0	4.64	0	0.76	0	3.53	0	0.14
PHILADELPHIA	0	0	2.75	0.63	0	0	1.07	-0.78	0	0	0.57	-0.62
PIKE	3.27	2.21	0	0	4.43	3.46	0	0	4.62	4.88	0	0
POTTER	0	1.48	0	0	0	3.76	0	0	0	4.49	0	0
SCHUYLKILL	3.63	-0.55	0	1.03	4.02	3.4	0	-0.85	3.54	5.3	0	-0.77
SNYDER	0	2.13	2.83	1.15	0	3.21	0.92	0	0	3.81	0.15	-0.3
SOMERSET	3.57	0.58	2.5	0.66	3.96	3.98	0.25	-0.96	3.56	4.61	-0.49	-0.65
SULLIVAN	0	-0.52	0	0	0	-1.18	0	0	0	0.3	0	0
SUSQUEHANNA	3.48	2.77	2.8	1.27	4.22	3.99	0.87	0.06	4.07	4.72	0.06	-0.25
TIOGA	0	2.18	0	0	0	2.91	0	0	0	3.2	0	0
UNION	4.02	1.9	0	2.54	4.56	3.27	0	1.15	3.73	3.65	0	-0.11
VENANGO	3.44	0.83	0	0.26	3.95	3.51	0	-1.2	3.51	3.88	0	-0.67
WARREN	0	1.12	0	0.45	0	3.5	0	-1.01	0	3.9	0	-0.61
WASHINGTON	3.7	0.01	2.73	0.91	4.02	3.84	0.41	-0.88	3.63	3.93	0.05	-0.55
WAYNE	3.77	2.06	0	2.37	4.36	3.83	0	0.8	4.11	4.26	0	-0.07
WESTMORELAND	3.57	0.35	2.64	0.7	3.89	3.98	0.38	-1.01	3.59	4.27	-0.2	-0.63
WYOMING	0	2.75	0	0.54	0	5.2	0	-1.04	0	4.82	0	-0.59
YORK	3.79	0.98	3	1.77	4.11	2.69	1.32	0.47	3.79	2.58	0.8	-0.08

Table D-4. Forecasted Growth Rates Based on County-Group Level OLS Model HH

GR Model	Rates between 2003 - 2010				Rates between 2010 - 2020				Rates between 2020 - 2030			
GROUP	CAT A	CAT B	CAT C	CAT D	CAT A	CAT B	CAT C	CAT D	CAT A	CAT B	CAT C	CAT D
ALTGR	1.73	0.38	0.93	-0.36	1.74	-0.45	0.81	-0.69	1.56	-1.84	0.51	-1.35
CNTRGR	2.43	0.9	1.53	0.86	2.47	0.11	1.43	0.51	2.37	-1.16	1.18	-0.14
EPAGR	2.15	0.95	1.47	1.45	2.27	0.1	1.39	0.99	2.3	-1.08	1.21	0.35
HARRGR	2.28	1.38	1.64	1.92	2.3	0.53	1.51	1.45	2.28	-0.64	1.3	0.78
I81GR	1.67	0.62	0.95	-0.12	1.75	-0.19	0.88	-0.46	1.72	-1.39	0.68	-1.02
NCNTGR	0	0.82	1.26	0.08	0	0.02	1.11	-0.22	0	-1.04	0.88	-0.69
NEPAGR	2.72	1.83	2.21	4	2.69	0.81	1.98	3.04	2.61	-0.34	1.69	2.08
NTIERGR	0	1.28	1.46	0.69	0	0.49	1.3	0.38	0	-0.55	1.06	-0.08
PHILY	2.28	1.07	1.45	0.78	2.33	0.26	1.36	0.43	2.29	-0.86	1.17	-0.11
SEDA-COG	2.11	0.75	1.32	0.67	2.15	-0.04	1.22	0.33	2.08	-1.31	0.98	-0.3
SHVGR	1.97	0.51	1.14	0.14	2.01	-0.28	1.05	-0.19	1.89	-1.6	0.78	-0.82
SWPAC	2.14	0.61	1.23	0.05	2.24	-0.2	1.17	-0.3	2.27	-1.35	1.01	-0.84
WPAGR	2.09	0.89	0	0.12	2.05	0.08	0	-0.19	1.98	-0.99	0	-0.67

Table D-5. Forecasted Growth Rates Based on County-Level OLS Base Truck Model HH

Truck HH Model	Rates between 2003 - 2010				Rates between 2010 - 2020				Rates between 2020 - 2030			
COUNTY	CAT A	CAT B	CAT C	CAT D	CAT A	CAT B	CAT C	CAT D	CAT A	CAT B	CAT C	CAT D
ADAMS	0	0.59	0	1.98	0	0.33	0	1.61	0	-0.04	0	1.10
ALLEGHENY	0	0.47	1.50	-0.22	0	0.22	1.58	-0.46	0	-0.15	1.58	-0.85
ARMSTRONG	0	0.51	1.49	0.35	0	0.26	1.61	0.11	0	-0.04	1.63	-0.20
BEAVER	1.82	0.49	1.67	0.36	1.82	0.24	1.71	0.13	1.75	-0.11	1.71	-0.24
BEDFORD	2.57	0.63	0	0	2.29	0.34	0	0	1.96	0.01	0	0
BERKS	2.07	0.48	1.99	1.28	2.02	0.23	1.98	0.98	1.86	-0.14	1.89	0.54
BLAIR	1.17	0.32	1.02	-0.32	1.14	0.05	1.05	-0.56	0.94	-0.38	0.93	-1.00
BRADFORD	0	0.67	1.77	0.66	0	0.42	1.75	0.44	0	0.10	1.69	0.13
BUCKS	2.52	0.80	2.42	2.23	2.37	0.53	2.32	1.86	2.16	0.21	2.16	1.43
BUTLER	2.64	0.64	2.56	2.08	2.41	0.37	2.39	1.73	2.07	-0.01	2.12	1.25
CAMBRIA	0	0.26	0.55	-0.93	0	-0.02	0.53	-1.22	0	-0.62	0.24	-1.90
CAMERON	0	0.24	0	0	0	-0.01	0	0	0	-0.39	0	0
CARBON	2.20	0.51	2.07	0.90	2.26	0.27	2.18	0.62	2.22	-0.04	2.19	0.27
CENTRE	2.63	0.68	2.51	1.67	2.55	0.44	2.47	1.35	2.23	-0.03	2.23	0.75
CHESTER	2.99	0.79	2.91	2.63	2.83	0.52	2.79	2.16	2.52	0.16	2.54	1.61
CLARION	2.16	0.74	0	0.71	2.03	0.46	0	0.49	1.83	0.10	0	0.13
CLEARFIELD	2.38	0.57	2.22	0.79	2.25	0.32	2.15	0.56	2.00	-0.07	1.98	0.15
CLINTON	1.27	0.41	1.15	0.32	1.63	0.20	1.54	0.06	1.57	-0.17	1.54	-0.37
COLUMBIA	1.83	0.51	1.73	1.04	1.90	0.28	1.83	0.78	1.78	-0.11	1.78	0.33
CRAWFORD	1.73	0.40	1.59	0.18	1.59	0.13	1.51	-0.03	1.30	-0.30	1.31	-0.46
CUMBERLAND	2.54	0.68	2.52	2.81	2.48	0.43	2.49	2.29	2.28	0.01	2.34	1.59
DAUPHIN	2.12	0.46	2.01	0.86	2.01	0.20	1.95	0.58	1.87	-0.18	1.88	0.14
DELAWARE	0	0.55	1.60	0.58	0	0.31	1.65	0.34	0	-0.06	1.63	-0.06
ELK	0	0.65	0	-0.03	0	0.36	0	-0.24	0	0.04	0	-0.53
ERIE	1.77	0.43	1.63	0.33	1.73	0.18	1.64	0.11	1.48	-0.26	1.48	-0.35
FAYETTE	0	0.51	1.61	0.28	0	0.25	1.64	0.02	0	-0.16	1.58	-0.40
FOREST	0	0.46	0	0	0	0.29	0	0	0	-0.06	0	0
FRANKLIN	2.08	0.82	1.94	1.62	1.99	0.54	1.90	1.35	1.88	0.21	1.85	0.98
FULTON	2.86	0.77	0	0	2.50	0.46	0	0	2.12	0.12	0	0
GREENE	1.95	0.53	0	0.40	1.83	0.27	0	0.21	1.49	-0.22	0	-0.32
HUNTINGDON	2.27	0.51	0	0.51	2.06	0.26	0	0.33	1.61	-0.30	0	-0.27
INDIANA	0	0.63	1.99	0.60	0	0.40	2.00	0.39	0	0.01	1.93	0.00
JEFFERSON	1.63	0.49	0	0.15	1.58	0.23	0	-0.06	1.47	-0.11	0	-0.38
JUNIATA	0	0.49	0	0	0	0.23	0	0	0	-0.08	0	0
LACKAWANNA	1.31	0.41	1.15	-0.19	1.30	0.16	1.19	-0.41	1.18	-0.20	1.14	-0.78
LANCASTER	2.39	0.71	2.30	1.98	2.31	0.45	2.26	1.63	2.16	0.11	2.16	1.17
LAWRENCE	1.49	0.47	1.35	0.33	1.65	0.25	1.54	0.09	1.71	-0.08	1.66	-0.27
LEBANON	1.86	0.53	0	1.11	1.80	0.28	0	0.84	1.69	-0.08	0	0.40
LEHIGH	2.14	0.47	2.05	1.26	2.17	0.23	2.13	0.95	2.07	-0.13	2.08	0.49
LUZERNE	1.34	0.37	1.19	-0.11	1.33	0.13	1.23	-0.34	1.17	-0.27	1.15	-0.74
LYCOMING	1.82	0.48	1.66	0.25	1.72	0.21	1.62	0.04	1.55	-0.16	1.52	-0.34
MCKEAN	0	0.55	1.75	0.26	0	0.28	1.61	0.08	0	-0.15	1.36	-0.35
MERCER	1.45	0.44	1.30	0.18	1.45	0.21	1.35	-0.04	1.27	-0.20	1.25	-0.48
MIFFLIN	0	0.41	1.48	0.12	0	0.15	1.48	-0.10	0	-0.18	1.44	-0.41
MONROE	2.99	0.65	3.02	3.52	2.72	0.36	2.78	2.78	2.40	0.02	2.49	2.05
MONTGOMERY	2.07	0.57	1.96	1.26	1.98	0.32	1.92	0.99	1.82	-0.03	1.83	0.58
MONTOUR	2.91	0.71	0	0.83	2.59	0.42	0	0.61	2.33	0.03	0	0.22
NORTHAMPTON	0	0.48	1.86	1.61	0	0.24	1.91	1.27	0	-0.11	1.90	0.78
NORTHUMBERLAND	1.50	0.43	1.33	-0.16	1.46	0.18	1.34	-0.37	1.36	-0.18	1.31	-0.75
PERRY	0	0.56	0	2.27	0	0.29	0	1.84	0	-0.02	0.00	1.36
PHILADELPHIA	0	0	1.05	-0.47	0	0	1.15	-0.74	0	0	1.13	-1.20
PIKE	3.35	0.65	0	0	3.21	0.37	0	0	3.04	0.07	0	0
POTTER	0	0.61	0	0	0	0.32	0	0	0	0.03	0	0
SCHUYLKILL	1.49	0.61	0	0.15	1.50	0.37	0	-0.08	1.30	-0.05	0	-0.53
SNYDER	0	0.52	1.98	1.03	0	0.28	1.88	0.80	0	-0.16	1.62	0.36
SOMERSET	1.75	0.52	1.58	0.28	1.64	0.26	1.53	0.07	1.33	-0.17	1.31	-0.34
SULLIVAN	0	0.49	0	0	0	0.27	0	0	0	-0.15	0	0
SUSQUEHANNA	2.16	0.66	2.02	1.25	2.02	0.38	1.94	1.00	1.83	0.06	1.81	0.70
TIOGA	0	0.74	0	0	0	0.45	0	0	0	0.07	0	0
UNION	2.58	0.77	0	2.27	2.53	0.51	0	1.89	1.93	-0.21	0	0.89
VENANGO	1.68	0.53	0	-0.06	1.54	0.27	0	-0.26	1.36	-0.08	0	-0.60
WARREN	0	0.57	0	0.06	0	0.31	0	-0.16	0	-0.02	0	-0.46
WASHINGTON	1.99	0.55	1.83	0.45	2.01	0.32	1.89	0.22	1.99	-0.01	1.92	-0.11
WAYNE	2.43	0.58	0	2.18	2.38	0.33	0	1.75	2.23	-0.03	0	1.20
WESTMORELAND	2.00	0.54	1.82	0.33	1.95	0.29	1.82	0.11	1.83	-0.06	1.77	-0.23
WYOMING	0	0.46	0	0.41	0	0.21	0	0.16	0	-0.10	0	-0.17
YORK	2.13	0.51	2.05	1.43	2.06	0.25	2.03	1.10	1.89	-0.11	1.93	0.65

Table D-6. Forecasted Growth Rates Based on County-Level OLS Base Model HH – Tot LM Growth Rates

HH w Tot LM growth	Rates between 2003 - 2010				Rates between 2010 - 2020				Rates between 2020 - 2030			
COUNTY	CAT A	CAT B	CAT C	CAT D	CAT A	CAT B	CAT C	CAT D	CAT A	CAT B	CAT C	CAT D
ADAMS	0	0	0	2.84	0	-0.25	0	2.36	0	-0.61	0	1.68
ALLEGHENY	0	-0.13	3.62	0.22	0	-0.35	3.48	-0.17	0	-0.7	3.24	-0.77
ARMSTRONG	0	-0.09	3.82	1	0	-0.32	3.69	0.59	0	-0.61	3.49	0.1
BEAVER	3.8	-0.1	3.85	0.93	3.48	-0.34	3.7	0.56	3.04	-0.68	3.47	-0.01
BEDFORD	3.79	0.07	0	0	3.52	-0.22	0	0	3.2	-0.55	0	0
BERKS	4.07	-0.11	4.2	2.04	3.73	-0.35	4.02	1.59	3.28	-0.7	3.75	0.97
BLAIR	3.57	-0.3	3.47	0.27	3.24	-0.55	3.31	-0.11	2.73	-0.97	3.02	-0.74
BRADFORD	0	0.07	4.01	1.32	0	-0.17	3.86	0.99	0	-0.48	3.66	0.54
BUCKS	4.59	0.2	4.67	3.19	4.24	-0.06	4.45	2.68	3.84	-0.37	4.19	2.11
BUTLER	4.35	0.06	4.59	2.89	4.03	-0.21	4.37	2.44	3.6	-0.58	4.06	1.84
CAMBRIA	0	-0.37	3.18	-0.35	0	-0.64	2.99	-0.79	0	-1.22	2.54	-1.68
CAMERON	0	-0.35	0	0	0	-0.6	0	0	0	-0.97	0	0
CARBON	3.91	-0.07	4.09	1.49	3.56	-0.3	3.94	1.02	3.17	-0.58	3.74	0.48
CENTRE	4.24	0.1	4.46	2.37	3.92	-0.13	4.28	1.91	3.35	-0.59	3.9	1.12
CHESTER	4.6	0.22	4.87	3.51	4.22	-0.04	4.62	2.88	3.76	-0.4	4.29	2.17
CLARION	4.06	0.15	0	1.32	3.76	-0.12	0	1.01	3.35	-0.47	0	0.52
CLEARFIELD	3.88	0	4.1	1.29	3.59	-0.25	3.93	0.96	3.15	-0.63	3.65	0.41
CLINTON	3.86	-0.22	3.73	1.09	3.47	-0.39	3.64	0.53	2.99	-0.74	3.39	-0.11
COLUMBIA	4.07	-0.1	4.08	1.84	3.74	-0.31	3.94	1.39	3.25	-0.68	3.67	0.74
CRAWFORD	3.67	-0.2	3.75	0.71	3.38	-0.45	3.58	0.41	2.91	-0.87	3.28	-0.15
CUMBERLAND	4.69	0.08	4.83	3.91	4.28	-0.16	4.59	3.17	3.69	-0.55	4.21	2.2
DAUPHIN	3.87	-0.12	4.05	1.45	3.56	-0.38	3.87	1.06	3.08	-0.74	3.6	0.42
DELAWARE	0	-0.05	3.93	1.27	0	-0.28	3.78	0.89	0	-0.64	3.53	0.28
ELK	0	0.06	0	0.41	0	-0.22	0	0.13	0	-0.54	0	-0.25
ERIE	3.74	-0.17	3.81	0.9	3.44	-0.4	3.67	0.55	2.94	-0.83	3.36	-0.08
FAYETTE	0	-0.08	3.82	0.85	0	-0.33	3.66	0.45	0	-0.72	3.39	-0.17
FOREST	0	-0.13	0	0	0	-0.3	0	0	0	-0.64	0	0
FRANKLIN	4.5	0.2	4.4	2.57	4.17	-0.06	4.22	2.19	3.75	-0.38	3.99	1.64
FULTON	4.29	0.2	0	0	3.99	-0.11	0	0	3.65	-0.45	0	0
GREENE	3.82	-0.06	0	0.95	3.54	-0.31	0	0.67	2.98	-0.8	0	-0.03
HUNTINGDON	3.75	-0.06	0	0.95	3.51	-0.31	0	0.72	2.89	-0.86	0	-0.04
INDIANA	0	0.05	4.02	1.15	0	-0.18	3.88	0.81	0	-0.54	3.63	0.25
JEFFERSON	3.77	-0.11	0	0.74	3.46	-0.36	0	0.4	3.07	-0.68	0	-0.07
JUNIATA	0	-0.13	0	0	0	-0.36	0	0	0	-0.66	0	0
LACKAWANNA	3.66	-0.2	3.56	0.4	3.35	-0.44	3.42	0.05	2.92	-0.78	3.18	-0.49
LANCASTER	4.45	0.12	4.54	2.89	4.1	-0.13	4.34	2.38	3.66	-0.46	4.07	1.74
LAWRENCE	3.86	-0.14	3.78	1.03	3.52	-0.34	3.66	0.58	3.07	-0.64	3.46	-0.02
LEBANON	4.1	-0.08	0	1.92	3.79	-0.32	0	1.51	3.32	-0.66	0	0.87
LEHIGH	4.03	-0.12	4.2	1.98	3.68	-0.34	4.03	1.48	3.2	-0.69	3.77	0.81
LUZERNE	3.65	-0.24	3.58	0.48	3.34	-0.47	3.44	0.12	2.87	-0.85	3.17	-0.46
LYCOMING	3.75	-0.11	3.8	0.79	3.45	-0.37	3.65	0.48	3.01	-0.73	3.4	-0.06
MCKEAN	0	-0.04	3.84	0.78	0	-0.3	3.68	0.54	0	-0.73	3.37	-0.01
MERCER	3.79	-0.17	3.72	0.85	3.49	-0.39	3.58	0.49	3	-0.79	3.29	-0.14
MIFFLIN	0	-0.19	3.71	0.68	0	-0.44	3.56	0.34	0	-0.75	3.35	-0.13
MONROE	4.79	0.06	5.13	4.64	4.33	-0.22	4.77	3.69	3.83	-0.55	4.38	2.77
MONTGOMERY	4.14	-0.03	4.21	2.04	3.83	-0.27	4.04	1.64	3.4	-0.61	3.79	1.07
MONTOUR	3.87	0.16	0	1.15	3.61	-0.13	0	0.91	3.18	-0.51	0	0.4
NORTHAMPTON	0	-0.12	4.28	2.54	0	-0.35	4.11	2.01	0	-0.69	3.84	1.29
NORTHUMBERLAND	3.64	-0.17	3.6	0.37	3.33	-0.41	3.46	0.03	2.89	-0.75	3.22	-0.52
PERRY	0	-0.05	0	3.33	0	-0.3	0	2.74	0	-0.6	0	2.08
PHILADELPHIA	0	0	3.47	0.09	0	0	3.33	-0.37	0	0	3.05	-1.05
PIKE	5.02	0.07	0	0	4.43	-0.18	0	0	3.85	-0.47	0	0
POTTER	0	0.03	0	0	0	-0.25	0	0	0	-0.53	0	0
SCHUYLKILL	3.92	-0.01	0	0.83	3.61	-0.23	0	0.45	3.11	-0.64	0	-0.18
SNYDER	0	-0.07	4.13	1.71	0	-0.3	3.96	1.39	0	-0.74	3.64	0.84
SOMERSET	3.81	-0.08	3.81	0.86	3.53	-0.33	3.66	0.57	3.07	-0.75	3.36	0.02
SULLIVAN	0	-0.12	0	0	0	-0.32	0	0	0	-0.72	0	0
SUSQUEHANNA	4.19	0.06	4.24	2.01	3.88	-0.21	4.07	1.66	3.53	-0.52	3.85	1.25
TIOGA	0	0.15	0	0	0	-0.13	0	0	0	-0.52	0	0
UNION	4.56	0.18	0	3.21	4.19	-0.07	0	2.65	3.32	-0.78	0	1.37
VENANGO	3.72	-0.06	0	0.46	3.44	-0.32	0	0.18	3.04	-0.66	0	-0.3
WARREN	0	-0.04	0	0.71	0	-0.3	0	0.37	0	-0.61	0	-0.07
WASHINGTON	3.84	-0.03	3.92	1	3.53	-0.26	3.78	0.62	3.12	-0.56	3.58	0.11
WAYNE	4.39	-0.01	0	3.09	4.01	-0.25	0	2.47	3.52	-0.59	0	1.71
WESTMORELAND	3.78	-0.05	3.88	0.84	3.48	-0.28	3.73	0.49	3.07	-0.62	3.5	-0.01
WYOMING	0	-0.18	0	1.31	0	-0.4	0	0.83	0	-0.69	0	0.27
YORK	4.13	-0.09	4.26	2.21	3.79	-0.33	4.07	1.73	3.33	-0.68	3.8	1.1

Table D-7. Forecasted Growth Rates Based on County-Level OLS Base Model HH – Half LM Growth Rates

HH w 1/2 LM growth	Rates between 2003 - 2010				Rates between 2010 - 2020				Rates between 2020 - 2030			
COUNTY	CAT A	CAT B	CAT C	CAT D	CAT A	CAT B	CAT C	CAT D	CAT A	CAT B	CAT C	CAT D
ADAMS	0	0.26	0	2.75	0	0	0	2.28	0	-0.36	0	1.59
ALLEGHENY	0	0.13	3.11	0.14	0	-0.1	2.97	-0.26	0	-0.44	2.73	-0.86
ARMSTRONG	0	0.16	3.31	0.91	0	-0.06	3.18	0.5	0	-0.36	2.99	0.01
BEAVER	3.62	0.15	3.34	0.85	3.31	-0.08	3.19	0.47	2.86	-0.42	2.96	-0.09
BEDFORD	3.62	0.33	0	0	3.35	0.04	0	0	3.03	-0.29	0	0
BERKS	3.89	0.15	3.68	1.95	3.56	-0.1	3.51	1.5	3.11	-0.45	3.24	0.88
BLAIR	3.39	-0.04	2.96	0.19	3.07	-0.29	2.81	-0.19	2.56	-0.71	2.51	-0.82
BRADFORD	0	0.33	3.5	1.24	0	0.09	3.35	0.9	0	-0.22	3.15	0.46
BUCKS	4.41	0.46	4.16	3.11	4.06	0.2	3.94	2.6	3.67	-0.11	3.68	2.02
BUTLER	4.17	0.32	4.08	2.8	3.86	0.05	3.86	2.35	3.43	-0.32	3.55	1.76
CAMBRIA	0	-0.11	2.67	-0.43	0	-0.38	2.49	-0.87	0	-0.96	2.04	-1.76
CAMERON	0	-0.09	0	0	0	-0.34	0	0	0	-0.71	0	0
CARBON	3.74	0.19	3.58	1.4	3.39	-0.04	3.43	0.93	2.99	-0.33	3.23	0.4
CENTRE	4.06	0.36	3.95	2.28	3.74	0.13	3.77	1.83	3.18	-0.33	3.39	1.03
CHESTER	4.42	0.48	4.36	3.42	4.04	0.21	4.1	2.79	3.59	-0.14	3.78	2.08
CLARION	3.88	0.41	0	1.24	3.59	0.13	0	0.93	3.18	-0.22	0	0.43
CLEARFIELD	3.7	0.25	3.59	1.2	3.42	0.01	3.42	0.88	2.98	-0.37	3.15	0.33
CLINTON	3.69	0.04	3.22	1	3.3	-0.13	3.13	0.45	2.81	-0.49	2.88	-0.19
COLUMBIA	3.9	0.16	3.57	1.75	3.56	-0.05	3.43	1.3	3.08	-0.42	3.17	0.65
CRAWFORD	3.49	0.06	3.24	0.62	3.21	-0.2	3.07	0.32	2.74	-0.62	2.78	-0.24
CUMBERLAND	4.51	0.34	4.32	3.82	4.1	0.1	4.07	3.09	3.51	-0.3	3.7	2.12
DAUPHIN	3.7	0.14	3.54	1.36	3.38	-0.12	3.36	0.97	2.91	-0.48	3.09	0.34
DELAWARE	0	0.21	3.41	1.19	0	-0.02	3.27	0.8	0	-0.38	3.02	0.2
ELK	0	0.32	0	0.32	0	0.04	0	0.04	0	-0.28	0	-0.34
ERIE	3.57	0.09	3.3	0.81	3.27	-0.14	3.16	0.46	2.76	-0.58	2.85	-0.16
FAYETTE	0	0.17	3.31	0.77	0	-0.08	3.15	0.36	0	-0.46	2.88	-0.25
FOREST	0	0.13	0	0	0	-0.04	0	0	0	-0.38	0	0
FRANKLIN	4.32	0.46	3.88	2.49	4	0.2	3.71	2.1	3.58	-0.12	3.48	1.56
FULTON	4.12	0.46	0	0	3.81	0.14	0	0	3.48	-0.2	0	0
GREENE	3.64	0.2	0	0.86	3.36	-0.05	0	0.58	2.81	-0.54	0	-0.11
HUNTINGDON	3.57	0.2	0	0.86	3.33	-0.05	0	0.64	2.72	-0.6	0	-0.13
INDIANA	0	0.31	3.51	1.06	0	0.08	3.37	0.72	0	-0.29	3.12	0.17
JEFFERSON	3.6	0.14	0	0.66	3.29	-0.11	0	0.32	2.89	-0.43	0	-0.15
JUNIATA	0	0.13	0	0	0	-0.1	0	0	0	-0.4	0	0
LACKAWANNA	3.48	0.05	3.05	0.32	3.18	-0.18	2.91	-0.04	2.74	-0.53	2.67	-0.57
LANCASTER	4.27	0.38	4.03	2.8	3.93	0.13	3.83	2.29	3.49	-0.2	3.56	1.65
LAWRENCE	3.68	0.12	3.27	0.94	3.34	-0.09	3.15	0.5	2.89	-0.39	2.96	-0.11
LEBANON	3.93	0.18	0	1.83	3.61	-0.06	0	1.42	3.15	-0.4	0	0.79
LEHIGH	3.86	0.14	3.68	1.9	3.51	-0.08	3.52	1.4	3.03	-0.43	3.26	0.73
LUZERNE	3.47	0.02	3.07	0.4	3.16	-0.21	2.93	0.04	2.69	-0.6	2.67	-0.54
LYCOMING	3.57	0.15	3.29	0.7	3.27	-0.12	3.14	0.39	2.84	-0.48	2.89	-0.14
MCKEAN	0	0.21	3.33	0.69	0	-0.05	3.17	0.45	0	-0.47	2.86	-0.09
MERCER	3.62	0.09	3.21	0.76	3.32	-0.13	3.07	0.4	2.83	-0.53	2.79	-0.22
MIFFLIN	0	0.07	3.2	0.6	0	-0.18	3.05	0.25	0	-0.49	2.85	-0.22
MONROE	4.61	0.32	4.62	4.55	4.15	0.04	4.25	3.6	3.66	-0.29	3.87	2.68
MONTGOMERY	3.97	0.23	3.7	1.96	3.65	-0.01	3.53	1.55	3.23	-0.35	3.28	0.98
MONTOUR	3.69	0.42	0	1.07	3.43	0.13	0	0.82	3.01	-0.26	0	0.32
NORTHAMPTON	0	0.13	3.77	2.45	0	-0.09	3.6	1.92	0	-0.43	3.33	1.21
NORTHUMBERLAND	3.46	0.08	3.09	0.29	3.16	-0.16	2.95	-0.05	2.72	-0.5	2.72	-0.61
PERRY	0	0.21	0	3.25	0	-0.05	0	2.65	0	-0.35	0	2
PHILADELPHIA	0	0	2.96	0	0	0	2.82	-0.45	0	0	2.54	-1.13
PIKE	4.85	0.33	0	0	4.25	0.08	0	0	3.67	-0.21	0	0
POTTER	0	0.29	0	0	0	0.01	0	0	0	-0.28	0	0
SCHUYLKILL	3.75	0.25	0	0.75	3.44	0.03	0	0.37	2.94	-0.38	0	-0.26
SNYDER	0	0.19	3.61	1.63	0	-0.04	3.45	1.31	0	-0.48	3.13	0.75
SOMERSET	3.64	0.18	3.3	0.78	3.35	-0.08	3.15	0.48	2.89	-0.5	2.85	-0.06
SULLIVAN	0	0.14	0	0	0	-0.07	0	0	0	-0.47	0	0
SUSQUEHANNA	4.01	0.32	3.73	1.92	3.71	0.05	3.55	1.57	3.36	-0.26	3.34	1.16
TIOGA	0	0.41	0	0	0	0.12	0	0	0	-0.26	0	0
UNION	4.38	0.44	0	3.12	4.02	0.19	0	2.56	3.15	-0.52	0	1.28
VENANGO	3.55	0.19	0	0.38	3.27	-0.06	0	0.09	2.87	-0.41	0	-0.39
WARREN	0	0.21	0	0.63	0	-0.04	0	0.28	0	-0.35	0	-0.15
WASHINGTON	3.67	0.22	3.41	0.91	3.36	0	3.27	0.54	2.95	-0.3	3.07	0.02
WAYNE	4.21	0.25	0	3.01	3.84	0.01	0	2.38	3.35	-0.33	0	1.63
WESTMORELAND	3.61	0.21	3.36	0.75	3.31	-0.03	3.22	0.41	2.9	-0.36	2.99	-0.09
WYOMING	0	0.08	0	1.22	0	-0.15	0	0.74	0	-0.43	0	0.18
YORK	3.95	0.17	3.75	2.13	3.61	-0.08	3.56	1.64	3.16	-0.42	3.29	1.01

Table D-8. Forecasted Growth Rates Based on County-Group Level OLS Model HH – Tot LM Growth Rates

GR w Tot LM growth	Rates between 2003 - 2010				Rates between 2010 - 2020				Rates between 2020 - 2030			
GROUP	CAT A	CAT B	CAT C	CAT D	CAT A	CAT B	CAT C	CAT D	CAT A	CAT B	CAT C	CAT D
ALTGR	2.08	-0.95	2.64	0.05	2.08	-1.76	2.52	-0.29	1.91	-3.14	2.21	-0.95
CNTRGR	2.78	-0.43	3.25	1.28	2.82	-1.22	3.15	0.92	2.72	-2.47	2.89	0.27
EPAGR	2.5	-0.39	3.19	1.87	2.62	-1.23	3.11	1.41	2.65	-2.39	2.93	0.76
HARRGR	2.63	0.04	3.36	2.34	2.65	-0.8	3.23	1.86	2.63	-1.96	3.02	1.2
I81GR	2.01	-0.71	2.66	0.29	2.1	-1.51	2.59	-0.05	2.07	-2.69	2.39	-0.61
NCNTGR	0	-0.51	2.98	0.49	0	-1.31	2.83	0.19	0	-2.35	2.59	-0.28
NEPAGR	3.07	0.48	3.94	4.43	3.05	-0.53	3.7	3.47	2.96	-1.66	3.42	2.5
NTIERGR	0	-0.06	3.18	1.1	0	-0.84	3.02	0.79	0	-1.87	2.78	0.33
PHILY	2.63	-0.27	3.17	1.2	2.68	-1.07	3.08	0.84	2.64	-2.17	2.88	0.3
SEDA-COG	2.46	-0.58	3.03	1.08	2.5	-1.36	2.94	0.74	2.43	-2.62	2.69	0.11
SHVGR	2.32	-0.82	2.86	0.55	2.36	-1.6	2.76	0.22	2.24	-2.91	2.49	-0.41
SWPAC	2.49	-0.72	2.95	0.46	2.59	-1.52	2.88	0.11	2.63	-2.65	2.72	-0.43
WPAGR	2.44	-0.45	0	0.53	2.4	-1.25	0	0.22	2.33	-2.3	0	-0.27

Table D-9. Forecasted Growth Rates Based on County-Group Level OLS Model HH – Half LM Growth Rates

GR w Tot LM growth	Rates between 2003 - 2010				Rates between 2010 - 2020				Rates between 2020 - 2030			
GROUP	CAT A	CAT B	CAT C	CAT D	CAT A	CAT B	CAT C	CAT D	CAT A	CAT B	CAT C	CAT D
ALTGR	1.91	-0.28	1.79	-0.16	1.91	-1.11	1.67	-0.49	1.74	-2.49	1.36	-1.15
CNTRGR	2.6	0.23	2.39	1.07	2.65	-0.56	2.29	0.71	2.54	-1.82	2.03	0.07
EPAGR	2.33	0.28	2.33	1.66	2.44	-0.57	2.25	1.2	2.47	-1.73	2.07	0.56
HARRGR	2.46	0.71	2.5	2.13	2.47	-0.14	2.37	1.65	2.45	-1.3	2.16	0.99
I81GR	1.84	-0.05	1.8	0.08	1.93	-0.86	1.73	-0.25	1.9	-2.04	1.53	-0.81
NCNTGR	0	0.15	2.12	0.28	0	-0.65	1.97	-0.02	0	-1.7	1.74	-0.49
NEPAGR	2.89	1.16	3.07	4.21	2.87	0.14	2.84	3.25	2.78	-1.01	2.56	2.29
NTIERGR	0	0.6	2.32	0.9	0	-0.18	2.16	0.59	0	-1.21	1.92	0.13
PHILY	2.45	0.4	2.31	0.99	2.51	-0.41	2.22	0.63	2.47	-1.52	2.02	0.1
SEDA-COG	2.29	0.08	2.18	0.87	2.33	-0.7	2.08	0.53	2.25	-1.96	1.84	-0.1
SHVGR	2.15	-0.15	2	0.35	2.18	-0.94	1.91	0.01	2.06	-2.26	1.63	-0.62
SWPAC	2.31	-0.05	2.09	0.25	2.41	-0.86	2.02	-0.09	2.45	-2	1.87	-0.63
WPAGR	2.26	0.22	0	0.32	2.22	-0.59	0	0.01	2.15	-1.65	0	-0.47

Table D-10. Averaged Annual Growth Rates (for Interstate Categories)

Model	Facility	1994-03	2003-10	2010-20	2020-30
Averaged Rates for Interstates (HH+CntyGrp) - Same LM	Rural Interstates	4.09%	2.93%	2.83%	2.58%
	Rural Non-Interstates	-0.87%	0.48%	0.24%	-0.13%
	Urban Interstates	4.12%	2.23%	2.16%	2.00%
	Urban Non-Interstates	1.73%	1.41%	1.07%	0.57%
	Total	1.54%	1.49%	1.31%	1.03%
Averaged Rates for Interstates (HH+CntyGrp) - Tot LM Growth	Rural Interstates	4.09%	3.28%	3.18%	2.93%
	Rural Non-Interstates	-0.87%	-0.03%	-0.28%	-0.64%
	Urban Interstates	4.12%	3.59%	3.48%	3.28%
	Urban Non-Interstates	1.73%	1.58%	1.25%	0.74%
	Total	1.54%	1.75%	1.67%	1.52%
Averaged Rates for Interstates (HH+CntyGrp) - Half LM Growth	Rural Interstates	4.09%	3.11%	3.00%	2.76%
	Rural Non-Interstates	-0.87%	0.23%	-0.02%	-0.39%
	Urban Interstates	4.12%	2.91%	2.82%	2.63%
	Urban Non-Interstates	1.73%	1.50%	1.16%	0.65%
	Total	1.54%	1.62%	1.48%	1.25%

Appendix E. Summary Tables of Data and Studies

Table E-1. HMPS Database aggregation to Functional Categories

FEDERAL HIGHWAY CLASSIFICATION		
Functional Classification	Description	VMT Forecasting System Functional Categories
Rural		
01	Interstate	Category A
02	Other Principal Arterial	Category B
06	Minor Arterial	Category B
07	Major Collector	Category B
08	Minor Collector	Category B
09	Local	Category B
Urban		
11	Interstate	Category C
12	Other Freeway/Expressway	Category C
14	Other Principal Arterials	Category D
16	Minor Arterial	Category D
17	Collector	Category D
19	Local	Category D

Table E-2. Descriptive Statistics by Functional Group

Rural Interstates

Variable	Obs	Mean	Std. Dev	Min	Max
Year	434	1998.555	2.855719	1994	2003
INC_Low	434	0.2516567	0.0593653	0.106	0.371
INC_VHigh	434	0.1507373	0.0742201	0.067	0.439
Pop17	434	0.2331313	0.0185871	0.174	0.271
Pop65+	434	0.1597949	0.0225673	0.096	0.204
Ln_HH	434	10.68282	0.9267186	8.586346	12.60115
Ln_INCHH	434	10.94149	0.2009428	10.59768	11.70263
Ln_INCPC	434	10.01877	0.1965541	9.650078	10.73285
Ln_Pop	434	11.63982	0.9216653	9.560152	13.5556
Ln_VMTA	434	19.05257	0.7422932	16.55452	20.38007
Ln_LMA	434	4.47632	0.7167639	2.282382	5.595974
LNLMAPC	434	-7.163496	1.154841	-11.05416	-4.477458

Rural Non-Interstates

Variable	Obs	Mean	Std. Dev	Min	Max
Year	660	1998.5	2.87446	1994	2003
INC_Low	660	0.2581667	0.0597614	0.106	0.399
INC_VHigh	660	0.141603	0.0704938	0.047	0.439
Pop17	660	0.2349697	0.0182304	0.174	0.277
Pop65+	660	0.1615561	0.0231499	0.096	0.225
Ln_EMP	660	10.68953	1.221152	7.609862	13.70912
Ln_HH	660	10.44137	1.140835	7.552762	13.20491
Ln_INCHH	660	10.92603	0.1937604	10.54276	11.70263
Ln_INCPC	660	10.00405	0.1891247	9.650078	10.73285
Ln_Pop	660	11.39535	1.141005	8.491876	14.10202
Ln_VMTB	660	19.83448	0.673214	16.42299	21.24498
Ln_LMB	660	7.700081	0.6403377	4.151984	8.619741
LNLMBPC	660	-3.695269	1.232235	-9.07359	-1.455964

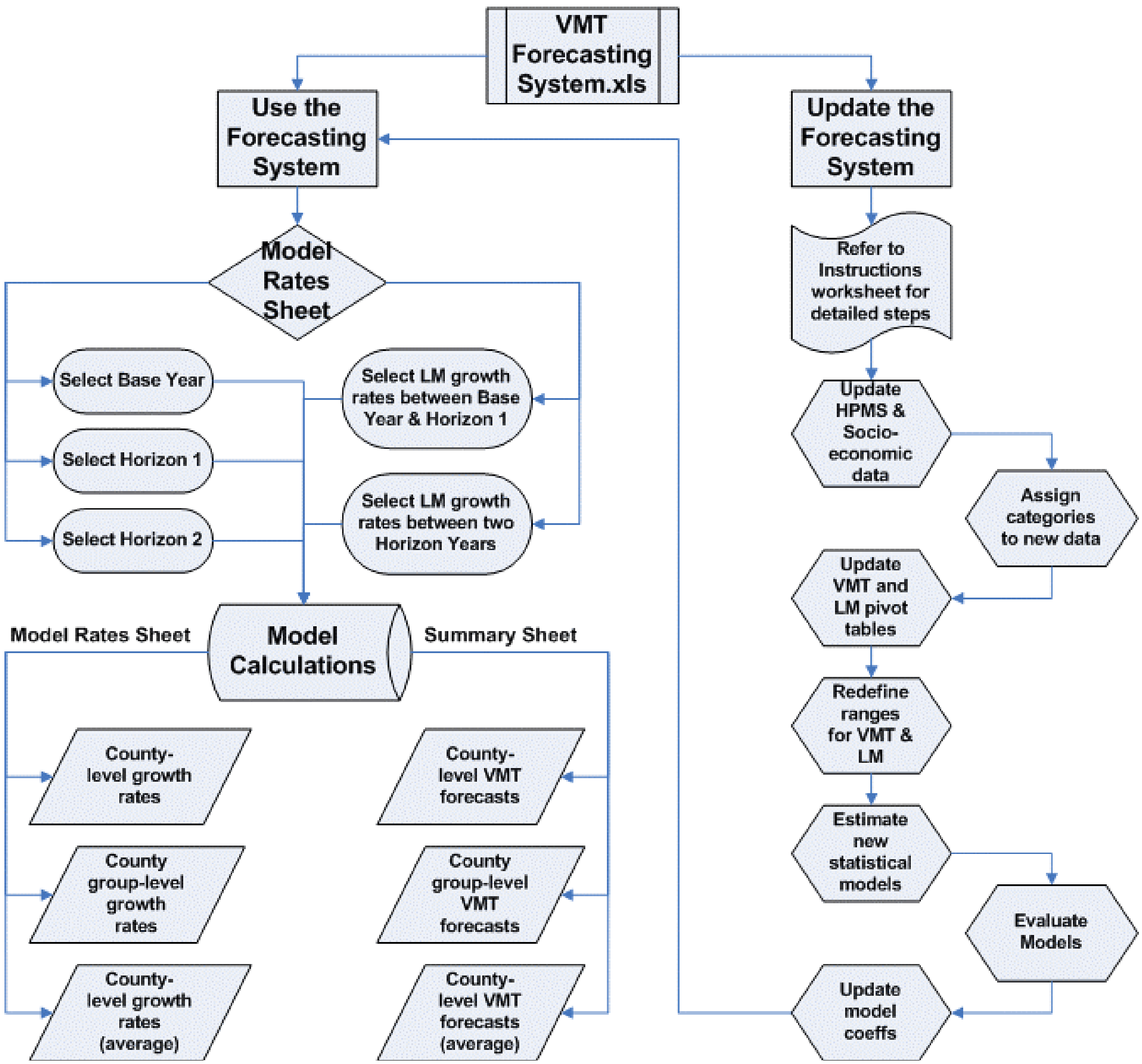
Urban Interstates

Variable	Obs	Mean	Std. Dev	Min	Max
Year	421	1998.511	2.880642	1994	2003
Ln_EMP	421	11.38946	0.9940644	9.6435	13.7091
Ln_HH	421	11.09865	0.9036711	9.4817	13.3042
Ln_INCHH	421	10.97561	0.2070614	10.6773	11.7026
Ln_INCPC	421	10.05504	0.1987715	9.7415	10.7328
Ln_Pop	421	12.04917	0.9031036	10.5295	14.2657
Ln_VMTC	421	18.7076	1.628664	15.7073	21.7575
Ln_LMC	421	3.978961	1.236713	1.67896	6.54435
LNVMTCPC	421	6.65842	0.8929743	4.31613	8.28033
LNLMCPC	421	-8.070216	0.642233	-9.73278	-6.85247
Ln_POPDEN	421	5.572744	1.118894	3.73404	9.3054
Ln_EMPDEN	421	4.91303	1.189631	2.84312	8.61248
Ln_COMBDEN	421	6.236654	1.151051	4.3053	9.97182
Ln_LUMIX	421	10.72468	0.9462911	9.0651	12.9472

Urban Non-Interstates

Variable	Obs	Mean	Std. Dev	Min	Max
Year	544	1998.533	2.890068	1994	2003
Ln_EMP	544	11.10114	1.050332	9.3426	13.7091
Ln_HH	544	10.82495	0.9790381	8.8303	13.3042
Ln_INCHH	544	10.9592	0.1945581	10.5977	11.7026
Ln_INCPC	544	10.03762	0.1888516	9.6501	10.7328
Ln_Pop	544	11.77986	0.9728314	9.8015	14.2657
Ln_VMTD	544	19.42156	1.441886	15.3064	22.6153
Ln_LMD	544	6.293646	1.387897	2.18155	9.32112
LNVMTCPD	544	7.641694	0.6093985	5.07312	8.63603
LNLMCPD	544	-5.486218	0.602522	-8.42914	-4.52322
Ln_POPDEN	544	5.344677	1.108069	3.72065	9.3054
Ln_EMPDEN	544	4.665955	1.183734	2.84312	8.61248
Ln_COMBDEN	544	6.00001	1.141315	4.3053	9.97182
Ln_LUMIX	544	10.44283	1.012275	8.6162	12.9472

Figure E-1. Flowchart for A Prototype VMT Forecasting System File



The VMT Forecasting System file is a prototype Vehicle Mile of Travel (VMT) growth forecasting system, which produces VMT forecasts and VMT growth rates at the county, county group and state levels. This VMT growth forecasting system is based on the County-level Household model (Model HH) and County Group Household model (Model CntyGrp HH) as developed and recommended in this final report. Both models use variables such as population, households and mean household income as well as road lane miles (LM). Socioeconomic data source is the state profile created by Woods & Poole Economics Inc., and traffic data are derived from PENNDOT TIS and RMS databases.

The purpose of this file is to offer a user-friendly platform for PENNDOT to forecast VMT and VMT growth rates for different years based on its needs. These forecasts can be calculated between a Base Year and a future year (Horizon 1) or between two future years (Horizon 1 to Horizon 2), all of which are user-defined. In the main text of this technical report as well as in the appendices the county, county group or statewide growth rates presented use the same base year (in this study is 2003) LM for all horizon years assuming no growth. The file, however, offers the option to increase/decrease the state lane miles to account for possible changes, which occur due to roadway reclassification, road construction/closure and change in area types between urban and rural areas. The results are being automatically calculated (with the help of some macros) and the results are in two worksheets.

The "Model Rates" worksheet contains the model rates for each county and county group based on the HH Model, County Group HH Model and an average between the two models. Because the average rate is generated by comparing total statewide VMT between the two models, two different methods have been adopted to disaggregate the statewide average to the county-level detail. The "Summary" worksheet contains the actual VMT forecasts based on the rates described in the "Model Rates" worksheet. The VMT forecast results, combined with the historical trends, can be illustrated into a series of VMT charts, using macros.

Currently, the file's predictive capabilities allow it to give forecasts until 2030 based on 2003 data and models. In the future as more data become available PENNDOT will have three options for future predictions:

1. Do nothing alternative: Use the file as it is (only the left leg of the Figure E-1) and change the two horizon years.
2. Simple update alternative (recommended only for small year-to-year changes): Incorporate the new VMT and LM into the "1994-2003 All Public Roads" worksheet and follow the first six steps of the right flowchart leg to update the traffic data.
3. Full update alternative (recommended for big changes and longer time intervals): Follow the whole Figure E-1 flowchart starting from the right leg going all the way down and back to the left leg.

Table E-3. Summary of Variables Used in Different Studies

Source	Benjamin 1986	Crouch & Seaver & Chatterjee 2001	Iskander & Jaraiedi & Thomas 1996	Harmatuck 1997	Indiana Report 2002	Kentucky Report 2000	Mohamad & Sinha & Kuczek & Scholer 1998	Morey & Niemeier & Limanond Model 1 2002	Morey & Niemeier & Limanond Model 2 2002	Noland Model 1999	Noland & Cowart 2000	Oregon Report 2000	Parthasarathi & Levinson & Karamalaputi 2004	Pushkar & Hollingworth & Miller 2000 VKT model	Qiao & Yu 2004	Saha & Fricker 1996
Dependent Variable																
VMT					X	X		X	X	X	X	X	X (change)	X	X	
AADT	X	X (for non bridge)	X	X			X									X
Independent Variables																
Demographic																
Age					X											
County households																X
County population			X			X	X						X			X
HHSize					X									X		
State households																X
State population										X						X
Year			X			X					X		X			X
Economic																
Consumer price index																X
County driving licenses			X		X											
County employment			X			X										X
County vehicle registrations			X													X
Gross National Product																X
Income			X		X									X		
Per capita disposable personal income										X	X					X
State employment																X
State vehicle registrations																X
US gasoline prices										X	X	X				X
Vehicle ownership / HH					X									X		
Land Use																
Area type - Location (urban, rural)							X	X (%)								
Land-use mix	X													X		
Population density					X						X					
Highway and Accessibility																
Accessibility index							X							X		
Number of jobs within a 5-km radius														X		
ADT		X (mean)		X											X	
Density of paved roads									X							
Distance to CBD														X		
Intersection per road kilometer														X		
Miles of roadway			X				X			X	X				X	
Number of lanes													X			
Road Type (paved, unpaved)		X							X							
Rural grid road type														X		
VMT													X			

Table E-4. Summary of Model and Method Types

Model Type	Barr 2000	Benjamin 1986	Cervero & Hansen 2001	Crouch & Seaver & Chatterjee 2001	Fulton et al 2000	Iskander & Jaraiedi & Thomas 1996	Hansen & Huang 1997	Harmatuck 1997	Indiana 2002	Kentucky 2000	Mohamad & Sinha & Kuczek & Scholer 1998	Morey & Niemeier & Limanond 2002	Noland 1999	Noland & Cowart 2000	Oregon 2000	Parthasarathi & Levinson & Karamalaputi 2004	Pushkar & Hollingworth & Miller 2000 VKT model	Qiao & Yu 2004	Saha & Fricker 1996
Regression				X		X				X	X	X				X	X		X
Stepwise Regression																			X
Seemingly Unrelated Regression													x						
Two-Stage Least Square Regression			X		X									X					
Exponential Regression																		X	
Neural Networks										X									
Time Series		X					X	X					X						
Cross sectional	X						X												
Growth rates									X						X				